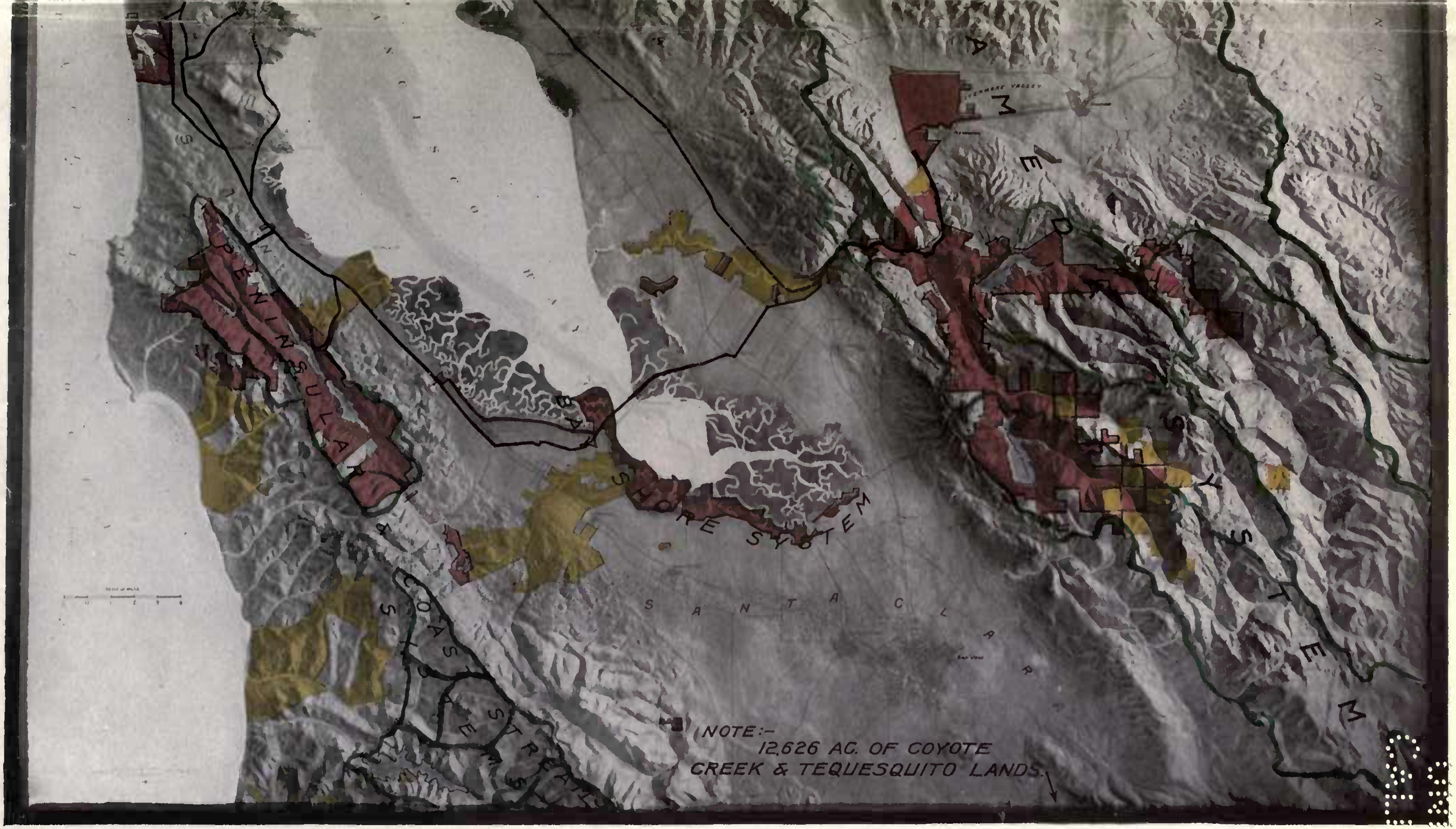
THE WATER SUPPLY OF SAN FRANCISCO

REPORT BY

H. M. CHITTENDEN


THE
WATER SUPPLY
OF
SAN FRANCISCO
LANDS OWNED IN FEE
ACRES
SAN FRANCISCO COUNTY 2.178
SAN MATEO " 29.710
ALAMEDA " 36.654
SANTA CLARA " 31.289
SAN BENITO " 691
TOTAL 100.522
RIPARIAN RIGHTS
ACRES
ALAMEDA CREEK 6.486
SAN MATEO " 4.474
COAST STREAMS & SAN FRANCISQUITO 32.438
CALAVERAS " 8.160
TOTAL 51.558
GRAND TOTAL - 152.080
PROPERTIES NOW DEVELOPED TO SUPPLY
45 MILLION GALLONS DAILY
PENINSULAR SYSTEM
36 Sq Miles of Watershed
Storage in Million Galls
Lake Pilarcitos 1.000
Lake San Andreas 6.000
Crystal Springs Lakes 23.000
Lake Merced 2.500
ALAMEDA SYSTEM
621 Sq Miles of Watershed
Sunol and Pleasanton Gravels (Subterranean)
PROPERTIES CAPABLE OF
FURTHER DEVELOPMENT TO SUPPLY
210 MILLION GALLONS DAILY
PENINSULAR SYSTEM
152 Sq Miles of Watershed
Storage in Million Galls
Lake Pilarcitos 1.000
Lake San Andreas 6.000
Crystal Springs Lakes 55.000
Lake Portola, - Coast Streams 32.900
Lake Merced 2.500
ALAMEDA SYSTEM
621 Sq Miles of Watershed
Calaveras Reservoir 55.000
San Antonio " 11.670
Arroyo Valle " 13.830
Gravel Storage at least 97.000 M.G. (Not Included)
TOTAL 177.900
210 MILLION GALLS. WILL CARE FOR CITYS NEEDS UNTIL 2000
NOTE
11 Pumping Stations in use. Capacity of 101 Mill Galls
87 Miles of Pipe Lines bet 54 and 30 diameter in use
11 City Distributing Reservoirs in use
460 Miles of City Pipe Lines bet 44 and 4 diameter in use
60.000 Service Connections in use
LEGEND
WATERSHEDS
LANDS OWNED IN FEE
RIPARIAN RIGHTS
RESERVOIRS
PIPE LINES
PIPE LINE EASEMENTS
PUMPING STATIONS
SPRING VALLEY WATER COMPANY.
SAN FRANCISCO
1912
PROPERTIES NOT SHOWN ON MAP - 13.336 ACRES



THE WATER SUPPLY OF SAN FRANCISCO.

137 Square Miles Owned for Water Supply Within a Radius of 50 Miles of San Francisco.

REPORT

ON

THE WATER SUPPLY SYSTEM

OF THE

SPRING VALLEY WATER COMPANY

SAN FRANCISCO, CAL.

BY

H. M. CHITTENDEN

Brigadier General, U. S. A. (Ret.),

Member American Society of Civil Engineers,

AND

A. O. POWELL

Member American Society of Civil Engineers.

"THE MEETING OF THE WATERS."

The Water Temple at Sunol. At this Place the Run-off from the Subdivisions of the Entire Alameda System Meets. Galleries Underlying the Sunol Valley Gravel Beds Collect the Filtered Water Which Pours in Great Volume into the Basin of the Temple, whence it is Conducted by Aqueduct to San Francisco.

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S. P. EASTMAN
Vice-President and Manager

EXECUTIVE DEPARTMENT

SPRING VALLEY WATER COMPANY

375 Sutter Street

SAN FRANCISCO, CAL., October 31, 1912.

The Honorable, the Secretary of the Interior, and The Advisory Board of Engineers, of the United States Army, Washington, D. C.

Sirs:

In accordance with a letter dated May 28, 1912, from the Secretary of the Interior, the Spring Valley Water Company herewith presents the report of Gen. H. M. Chittenden of Seattle, who was assisted by Mr. A. O. Powell, C. E., of Seattle, with reference to the safe dependable yield of water, which may be developed, from the existing resources of the properties of the Company now engaged in supplying San Francisco with water.

There is presented in another volume reports of the following:

Mr. Hermann Schussler, Consulting Engineer, and Mr. F. C. Herrmann, Chief Engineer, of the Spring Valley Water Company; Mr. George G. Anderson, Hydraulic Engineer of Denver, Colorado; Messrs. Wm. Mulholland and J. B. Lippincott of Los Angeles, Chief and Assistant Chief, Engineers of the Los Angeles Aqueduct; Prof. J. N. Le Conte, Hydraulic Engineer of the University of California; Dr. J. C. Branner, Vice-President and head of the Department of Geology of Stanford University; Dr. A. C. Lawson, head of the Department of Geology of the University of California; F. W. Roeding, Manager of Agriculture for the Company, and formerly Irrigation Manager of the Irrigation and Drainage Investigations of the Pacific Division, United States Department of Agriculture; and appendices of Mr. C. H. Lee of the United States Geological Survey, and Messrs. J. J. Sharon, T. W. Espy, I. E. Flaa and H. Monett, Assistant Engineers of the Company.

This report is submitted for your consideration.

Respectfully,

S. P. EASTMAN,

Vice-President and Manager Spring Valley Water Company.

REPORT ON THE WATER SUPPLY SYSTEM OF THE SPRING VALLEY WATER COMPANY, SAN FRANCISCO, CALIF.

BY

H. M. CHITTENDEN,

Brigadier General, U. S. A. (Ret.)
Member American Society of Civil Engineers

AND

A. O. POWELL,

Member American Society of Civil Engineers

Seattle, Washington, October 12, 1912.

Mr. S. P. Eastman, Vice-President Spring Valley Water Co.,

San Francisco, California.

Dear Sir:

1. In compliance with your request of August 26, I have prepared and herewith submit the following report concerning the water resources of the Spring Valley Water Company and their adequacy to meet the growing demands of the City of San Francisco. The report is based upon a careful review of a vast mass of documentary evidence, supplemented by conferences with those familiar with the conditions, and a personal inspection of the properties. With your consent I associated with me in this work A. O. Powell, member of the American Society of Civil Engineers, whose long experience in problems of stream-flow made his co-operation of especial value.

2. Owing to the prodigious bulk of the data submitted, I have thought that the most effective service which I could render, both to yourselves and the department of the government to which the matter is about to be referred, would be to group the salient features of the question into a concise brief with a statement of my conclusions and the reasons therefor, giving page references to the numerous documents for greater detail. In carrying out this plan the abbreviations shown below in parentheses will be used for reference.

REPORTS PREPARED FOR SPRING VALLEY WATER COMPANY.

(Schussler)—Report of Herman Schussler to the Spring Valley Water Company, dated May 1, 1912. Mr. Schussler was the founder and for forty years the Chief Engineer of the Company and is still its consulting engineer.

(Herrmann)—Report of F. C. Herrmann, M. Am. Soc. C. E., Chief Engineer of Spring Valley Water Company, dated October 1st, 1912, with appendices by J. J. Sharon, T. W. Espy, I. E. Flaa and H. Monett of the Engineering Corps of the Spring Valley Water Company.

(Anderson)—Report of George G. Anderson, M. Am. Soc. C. E., to the J. G. White Company, upon the sufficiency of the Alameda System, dated September 11th, 1912.

M. & L.—Reports of Wm. Mulholland, M. Am. Soc. C. E., and J. B. Lippincott, M. Am. Soc. C. E., Chief Engineer and Assistant Chief Engineer, respectively, of the Los Angeles Aqueduct Commission, dated February 2d, 1912, May 13th, 1912, and July 2d, 1912. Mr. Mulholland conceived, designed and built the celebrated Los Angeles Aqueduct.

(Le Conte)—Report of Professor J. N. Le Conte

HEADWATERS OF THE ALAMEDA SYSTEM.
A Characteristic View of the Rugged Mountainous Watershed of the Alameda System. Note the Lack of Possibility to Sustain Habitation. Taken in the Extremely Dry Season of 1911-12.

on tests of models of Niles and Sunol dams, to Spring Valley Water Company, dated June 22d, 1912.

(Branner)—Reports of Professor J. C. Branner on the geology of the Livermore Valley, dated December 1st, 1911, and May 6, 1912. Dr. Branner is Vice-President of Stanford University and in charge of the Department of Geology, and is a recent recipient of the Hayden medal.

REPORTS PREPARED FOR THE CITY OF SAN FRANCISCO.

(Freeman)—Report of John R. Freeman to the Mayor of San Francisco, dated July 15th, 1912.

(Williams)—Report of Cyril Williams to the City of San Francisco, dated March 26, 1912. Mr. Williams was for several years in the employ of the Spring Valley Water Company.

MISCELLANEOUS.

(Tibbetts)—Report of Mr. Fred C. Tibbetts, M. Am. Soc. C. E., Consulting Engineer, dated April 15th, 1912. This report was prepared in behalf of certain litigants with the Spring Valley Water Company.

Wherever references are made to "Appendix," they refer to the appendix to this report.

I.

FORECAST OF REQUIREMENTS.

Growth of Population.

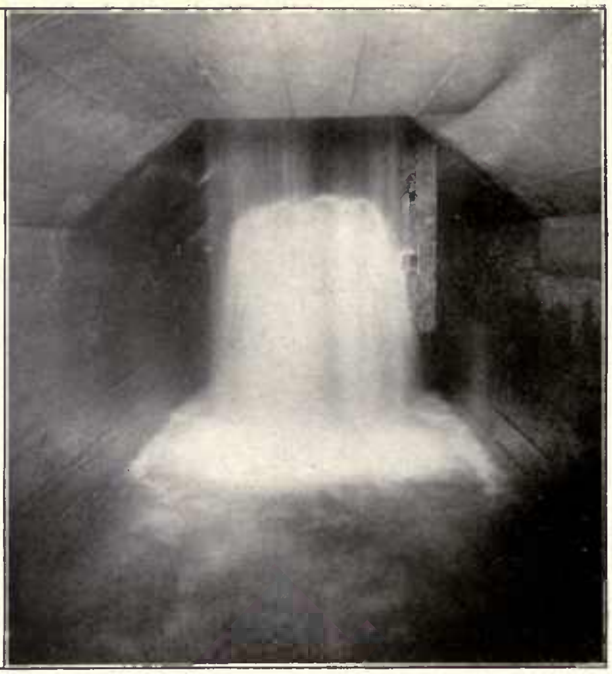
3. Estimates of the population of San Francisco in 1950, which is as far ahead as this report will venture to forecast, range from 800,000 to 1,500,000. The conclusion herein adopted is that a population of 875,000 is the limit that can be expected for San Francisco county alone. The percentages of increase assumed (Appendix A, Table II) are believed to be above the mark, if anything, because of the peculiar and almost unique conditions prevailing. The area is absolutely limited, the topography does not admit of a dense population, and large tracts are devoted to governmental, park and waterfront purposes. In recent years, the better class of residences are seeking outlying territory. Taking all into consideration, and with due reference to the growth of other cities, the assumed percentages must be accepted as all that can reasonably be expected.

4. For Greater San Francisco (the five Bay counties) the growth will be more rapid, and the rate adopted by Mr. Freeman is probably conservative. I have assumed somewhat different percentages but they lead practically to the same result, viz., about 2,000,000 for the year 1950. There is no sufficient reason to believe that this figure will be exceeded. It is fully up to the general experience of the country except in New York and Chicago, and no one believes that San Francisco, bright as its prospects are, will show a rate of growth like those two cities. The possible development of the hinterland upon which its own growth depends will not admit of it. (See Table I, Appendix A.)

5. These two assumptions, therefore—875,000 for San Francisco proper in 1950, and 2,000,000 for Greater San Francisco—form the basis of requirements for future water supply discussed in this report.

Per Capita Consumption.

6. From a comparative study of the experience of American cities, based largely upon recent correspondence, I am convinced that the figures assumed by Mr. Freeman, and even by Mr. Schussler, for the future per capita consumption of San Francisco are too high. While each city has its own peculiarities in this respect which make direct comparison impossible, it is certain that waste pure and simple forms a large percentage of the consumption where the per capita is high. The whole tendency of future development will be to reduce this waste and the meter will be an effective agency to that end. Of the many authorities consulted the opinion was unanimous on this point, and practically so that per capita consumption will not increase much in the future and in many cases will actually decrease. In San Francisco county the conditions will always sharply restrict per capita consumption. The coolness of the summer climate, the relative decrease of large residences with lawns, the extensive use (which will permanently continue) of water from the Bay and surface wells for condensers and similar purposes, and other less important considerations, make this reasonably certain. In the other Bay counties the rate will naturally be higher because of the greater sum-



FILTER GALLERY AT SUNOL. JUNCTION OF THE GALLERIES, SUNOL.
Subterranean Water Being Drawn from the Gravel Fill of Sunol Valley. Nearly Half San Francisco's Water Supply is Thus Drawn Daily.

THE BASIN OF THE WATER TEMPLE AT SUNOL.
Here the Filtered Water from the Galleries at Sunol Meet the Artesian Waters from Livermore Valley.

mer heat and the larger percentage of residences. But offsetting these influences is the fact that much of the territory is of artesian character and that a large local supply will always be drawn from wells, thus reducing the per capita from a general supply system.

7. On the whole, I believe that an increase of five gallons per decade in the per capita consumption for San Francisco and 10 gallons for the other Bay counties will more than allow for the current tendency toward greater luxury in the use of water, restrained as it will be by the causes above enumerated. As the two divisions of Greater San Francisco are approximately equal in population an increase of 7½ gallons per capita per decade is assumed for the whole. The results are set forth in Table III, Appendix A. For the year 1950 they give a consumption for San Francisco of 92 m. g. d.*, and for Greater San Francisco of 235 m. g. d. The estimate of 110 m. g. d. (Schussler) for San Francisco and 250 m. g. d. (Freeman) for the Greater San Francisco, I regard as being far on the side of safety.

II.

ADEQUACY OF SPRING VALLEY RESOURCES.

8. The supply resources of the Spring Valley Water Company to meet these growing demands will be considered in the order of their probable development, as follows:

The Peninsular System.
The Alameda System.
The Coast streams.
Artesian Supplies.
The Coyote System.
San Joaquin River.

The Peninsula System.

9. This consists of three reservoirs, one on the watershed of Pilarcitos Creek and two on the San Mateo. The details are set forth in Appendix C. The total watershed area is 36 square miles and the present maximum storage capacity of the reservoirs is about 30,000 million gallons.† The system is so interlaced by connecting tunnels that the yield of the entire watershed, except in the very wettest years, is conserved. The dependable supply is 19.5 m. g. d. The Company owns the watershed in fee simple. This was the first step in the development of the entire system.

The Alameda System.

10. Next in actual development, and first in importance in the present discussion, is the supply to be derived from Alameda Creek above Niles Canon. Broadly speaking, this resource, when fully developed, will embrace two distinct sources of supply—surface run-off and ground water. Development of the latter source commenced several years ago and an annual draft of 16 m. g. d. is now made from the Pleasanton wells in Livermore Valley and from the Sunol filter beds, so-called, at the head of Niles Canon. The Spring Valley Water Company places great store upon the possibilities of the Alameda system and Mr. Schussler has estimated as a conservative yield under proper development 120 m. g. d. (Schussler, p. 118.) With the more complete data now available, the present chief engineer, Mr. Herrmann, estimates a safe yield of 135 m. g. d. (Herrmann, p. 2.) In his report on the proposed Hetch Hetchy supply, Mr. Freeman challenges the validity of these claims, and holds that the system cannot yield more than 25 to 30 m. g. d. in addition to the present draft with the probability that it will be less (Freeman, p. 179). On this wide difference of expert opinion hangs, in large part, the question now pending before the Secretary of the Interior, and it becomes necessary to determine which view, if either, is correct.

The Total Alameda Run-off.

11. Assuming that the utmost that could ever be drawn from the watershed would be some percentage less than 100 of the natural outflow through Niles Canon, it becomes of first importance—"the one bedrock fact" (Freeman)—in this study to know what that outflow is. Records have been kept in a rather unsatisfactory way of the discharge heights over two dams across the creek in Niles Canon—one the Niles dam at the lower end of the canon from 1889 to 1899 and the other, the Sunol dam three miles further up near the head of the canon, from 1900 to the present time. Neither dam was built with a view to its use as a weir for measuring discharge and neither was well fitted for that purpose.

*Throughout this report the abbreviation "m. g. d." will be used for "million gallons daily."

†In this statement, Lake Merced, a natural reservoir of 2500 m. g. capacity, located within the city limits, is not included.

IN THE UPPER ALAMEDA SYSTEM.
View from Mt. Hamilton Showing the Precipitous Nature of the Watershed, Its Adaptability for Run-off Purposes and its Freedom from Habitation.

Mr. Schussler, however, in the course of several years' observations, made numerous measurements at different stages and sections of the stream of the water actually carried, and from these tests came to the conclusion that the ordinary Francis formula applied to the recorded gage heights would give approximately correct results, the discrepancy being uniformly on the side of safety. In view of this close approximation he ordered the records to be kept and worked upon this basis and they now constitute what are called the Company's "unrevised estimates" of the discharge of Alameda Creek in Niles Canon.

12. The accuracy of the Niles dam record was questioned in 1903 by Mr. J. B. Lippincott in U. S. G. S. Water Supply Paper No. 81, in which he reduced Mr. Schussler's figures from 141 to 99 m. g. d. Mr. Lippincott has recently discovered from original notes that the error was on the part of the Survey in not correctly recording the form and dimensions of the dam. The correction of this error (see letter from Mr. Lippincott to the Spring Valley Company, September 28, 1912) gives results practically confirming those of Mr. Schussler.

13. Recently the records have been severely assailed by Mr. Freeman, following an excessively voluminous report by Mr. Cyril Williams, particular emphasis being laid upon the effect of a misplaced decimal point "discovered by Mr. Williams" (Freeman, p. 180).* Except for this one error, however, which, by the way, was given an erroneous and exaggerated value, the only argument that I can discover in Mr. Freeman's criticism is that, because the record is inaccurate the results based upon it must be excessive. The possibility that they might be under the truth is nowhere admitted. Mr. Freeman appointed a board of eminent engineers to investigate the questions, but their findings have not been made public and apparently he has not used them in his report. The Spring Valley Water Company, on its part, has gone to heavy expense to get at the truth of the matter. A most elaborate recomputation and revision of the records has been made under the personal direction of George G. Anderson, member of American Society of Civil Engineers, and models of the two dams have been made under the direction of Professor Le Conte of the University of California, and special formula deduced therefrom. Other tests have been made by estimating the discharge from cross sections and slope. The net result of all these studies has been to show that the Company's unrevised estimates were conservative; that the dependable yield from the watershed is in excess of anything they have ever claimed, and that the criticisms of Messrs. Freeman and Williams are entirely unsubstantiated. The results, moreover, are in no sense unreasonable. The watershed is naturally fitted for a large percentage of run-off. The greater portion is very precipitous and therefore quick-spilling. The remaining portion is directly tributary to deep gravel beds of recent deposit and older gravels known to be pervious to water. As is always the case in such situations the proportion of water taken into the ground only to reappear as springs is large and the percentage of run-off correspondingly increased. *A total run-off of say 150 m. g. d. from such a watershed, equivalent to five inches uniform depth per annum, or 23 per cent of the average rainfall, should not be considered extraordinary.*

*The error was discovered by Mr. Schussler and corrected in court in 1905, and is recorded in the same minutes from which Mr. Freeman quotes.

14. Unless, therefore, some evidence to the contrary can be produced which is not yet forthcoming, the run-off of Alameda Creek as measured in Niles Canon must be taken as not less than the unrevised estimates of the Spring Valley Water Company of 132 m. g. d. (for 19 year period from 1889-90 to 1907-8), with the probability that it is considerably greater than this. (Examine particularly Captain Powell's review of the data on this question as given in Appendix B.)

The Dependable Yield.

15. The next question is—how far can this total run-off be utilized?—or what is the *dependable* supply from the watershed? The primary measure proposed in determining this question is the building of three storage reservoirs on the Calaveras, San Antonio and the Arroyo del Valle Creeks, their combined capacity being 76,000 m. g. Aided by pipe line connections of large capacity with the Crystal Springs reservoir as it will hereafter be enlarged, and possibly also with the enlarged Chabot, these reservoirs will be able to take care of nearly all the run-off of 312 square miles from which comes an average of 75 per cent of the total for the whole Alameda watershed.

16. Supplementary to this artificial storage it is proposed to extend and develop the use now being made of the two natural reservoirs already referred to, viz., the Livermore and Sunol gravel beds. This underground storage has been given a prominence in the pending controversy to which it is in no sense entitled, for with its utmost development it will constitute less than 25 per cent. of the Alameda system and not more than 15 per cent. of the entire Spring Valley system. But it has proven a favorite point of attack on the system, doubtless because it is mainly out of sight and unexplored and theories can be set up about it with the certainty that they cannot be assailed with positive proof. Men always become dogmatic in such circumstances and the case in hand is no exception.

17. The general features of the Alameda problem have been worked out in great detail by Mr. George G. Anderson, member of American Society of Civil Engineers, who has set forth a rational and easily followed exposition of the subject and has shown in general terms how the developed system may be manipulated to conserve the greater portion of the flow. Such studies are, of course, more or less theoretical and can never be an adequate substitute for long-kept, accurate records, but they have been pursued with such painstaking care in this instance and with the advantage of such long experience that they are entitled to great weight. They indicate a dependable yield of more than 140 m. g. d. The distribution independently arrived at by Mr. Herrmann, Chief Engineer of the Spring Valley Water Company, substantially confirms his conclusions.

The Gravel Reservoirs.

18. I shall not discuss at any length the scheme of surface storage, for there is no reasonable doubt of its complete practicability; but will consider somewhat in detail the gravel storage simply because it is being made such a bone of contention in the question now pending between the City and the Company. Stripped of the fog of controversy in which it has been unnecessarily enveloped, this "gravel reservoir" problem is not so complicated after all. It is not one that can be reduced to the same definite terms as one on the surface of the ground, but still it is one which has behind it a vast fund of experience. It is nothing new, unusual or unprecedented. One-half the water supply of the Bay cities comes from underground sources.

Thence comes all of that of Los Angeles, Fresno and other important cities. Probably fully half the domestic water supply of California towns comes from underground. Men experienced in these matters place the Livermore gravels in high comparison with other similar sources.* In fact they have a unique advantage, pointed out by Professor Branner, in the geologic formation of the valley which has fallen below the rim at its outlet, and has thus formed an immense subterranean dam. Into the basin behind this dam the flood waters through indefinite past ages have brought down the debris dislodged from the mountains. The coarser gravels are found all along the valley, near the surface in the upper portion and more deeply buried at the lower end. The finer material either drifted out to sea or accumulated in a covering over the gravels in the lower part of the valley. This covering, often spoken of as a "clay cap," though not strictly clay and not wholly impervious, gave rise to an artesian condition and wherever wells penetrated it the water would rise to or above the surface. In places the cap was badly broken up and a multitude of springs was the result. The gravel under-strata are not continuous, but lie in irregular beds formed as the streams wandered back and forth in the upbuilding of the valley. But that they are all connected, and that the water movement through them is comparatively free has been demonstrated beyond all doubt. (See measurements of F. H. Tibbetts, 1907.) Besides these recent beds there are vast fields of Pliocene gravels underlying the southern portion of the valley which are water-bearing and capable of immense storage. The Sunol beds at the head of Niles Canon are less extensive and deep, but are of cleaner and coarser gravel and are capable of large storage.

19. Now, from out this tangle of controversy over a question which can never be fully settled except as the outcome of long experience, what are the reasonable probabilities—such as would justify the investment of capital or the fore-

*Messrs. Mulholland and Lippincott give a most interesting comparison of the Livermore Valley with the San Fernando Valley from which the water supply of Los Angeles to the extent of forty-five m. g. d. is drawn. The controlling conditions in the two cases would lead one to expect a larger unit yield from the Livermore Basin.

casting of definite results in water production? Are these gravel reservoirs of sufficient capacity to supplement the proposed artificial reservoirs in such a way as to conserve practically all the run-off of the Alameda watershed? The area of the Pleasanton-Livermore beds, including the exposed gravels and those underneath the "clay cap" is not less than 30 square miles. Their depth is unknown but extends beyond any practical limit of pumping. Although attempts have been made to impose hard and fast limits to the depth to which the water can be drawn, these attempts are purely matters of personal opinion and are not sustained by arguments entitled to weight. The only limitation to drawing down these beds by pumping is the practical one of cost.* This relates to the cost of installation and pumping and that of adjusting damages to existing wells wherever such damage may be established. It does not affect the quantity of storage available which, as it seems to the writer, cannot possibly be taken at less than 25,000 m. g. even on the basis of 5 per cent average porosity. It is probably a great deal more. The Company claims fully three times this figure. Even the smaller storage is far in excess of the mean run-off of the unreservoired portion of the tributary watershed which cannot much exceed 32 m. g. d., though, of course, it will be much greater in wet years.†

20. The problem thus resolves itself into the practical one of getting water *into* the gravels and getting it *out*. As to the second part of the problem nothing will be said here because no one questions the complete practicability of pumping the water from the gravels. In the matter of inflow it is wholly a question of securing the necessary area of exposed gravels to absorb the waters as they come. For the most part the waters enter the Livermore gravels in the upper stretches of the valley where they come to the surface. For miles along the del Valle and the Mocho the gravel is exposed, and in a less degree along the Positas, while in the areas between it is concealed only by a thin layer of soil. The absorptive capacity of these gravels is, by actual observation, not less than 10 cubic feet per square foot per day where the beds are depleted, though it naturally diminishes as they become replenished. The area of stream bed exposed on the del Valle alone is more than a million square feet. It is entirely practicable to distribute the stream flow from the del Valle across to the Mocho or the reverse so that the flow of either stream may spread over the beds of both, and, by ditch work, this can be indefinitely extended over the area between. It is certain that a sufficient area of absorption can be developed to care for the unreservoired run-off *after* the del Valle reservoir is built. It would not be practicable before that time. At present high floods come down that valley in such quantity that the gravels do not have time to absorb them and they occasionally completely submerge the lower part of the basin, giving it the appearance of an immense lake. The reservoir will change all this. It will store the del Valle floods, and may also, if ever found desirable, be made to store a portion of the Mocho floods. This storage, far from depleting the gravel supply as Mr. Freeman asserts, will be the potent means of preserving and extending it. The floods can then be so handled that only a small portion of the waters will waste, while such as do pass off into Laguna Creek in surface flow can be conducted into the gravel beds at Sunol.

21. The margin of storage capacity in the Sunol gravels over the run-off of the unreservoired portion of the tributary watershed, including in this Alamo, Laguna and Sinbad Creeks, is much smaller than in the case of the Livermore gravels. The practicable storage, developed by deep pumping, would probably not exceed 6500 m. g. Mr. Herrmann makes a somewhat higher estimate. With the smaller figure, however, and with a continuous heavy draft during the period of high run-off, the gravels would apparently take care of all the flow which it would be practicable to bring into them except in times of sharp freshets.

22. With the brief exposition above given it would seem that this "gravel storage" problem should be easily comprehended. It is not a case of subterranean supply, as such—a great fountain replenished from no one knows where. It is a reservoir pure and simple, but under the ground instead of on top. Its source of supply

*Mr. Williams virtually admits this in the following quotation (Williams 358), though he finally adopts an altogether different view: "Were the entire area of the Livermore basin under the control of a single water company * * * the depth to which its ground water could be lowered would be limited only by the depth of the water strata and by the cost of extraction."

†I do not admit the practicability of taking Alamo Creek on to the gravels, but it appears practicable so to dispose of all the other north side streams.

ON THE PESCADERO.
A Portion of One of the Rock Abutments of the Damsite. Note the Log Which Has Been Thrown on the Bank by a Flood. This Picture of the Stream was Taken at the End of One of California's Driest Seasons.

is surface run-off from the tributary watershed and not a drop is counted on from anywhere else. If, instead of these reservoirs a dam were to be thrown across Alameda Creek at the head of Niles Canon and an artificial reservoir created behind it sufficient to store such run-off as could not be cared for by Calaveras, San Antonio and del Valle, the problem would appear in all its simplicity. But the function which such a reservoir would perform is only that which it is proposed to apply to the two natural reservoirs already in existence.

23. There has been some discussion in this connection about the true function of the del Valle reservoir. It has been treated by Messrs. Anderson and Herrmann principally as a regulating reservoir to control the floods and bring them onto the gravels no faster than they could be absorbed. They have considered that a capacity of 12,500 m. g. is sufficient for this purpose. It is understood that the site will admit of a reservoir of 20,000 capacity. If this is the case, it would seem that this greater storage, and the delivery of the water by gravity instead of pumping from the gravels might be an advantage. It would avoid to that extent, moreover, the effect of the gravel beds in mineralizing the water, and might also reduce the cost necessary to a wider distribution over the intake gravels. Whether these advantages would offset the greater cost of the enlarged reservoir will require further study to determine.

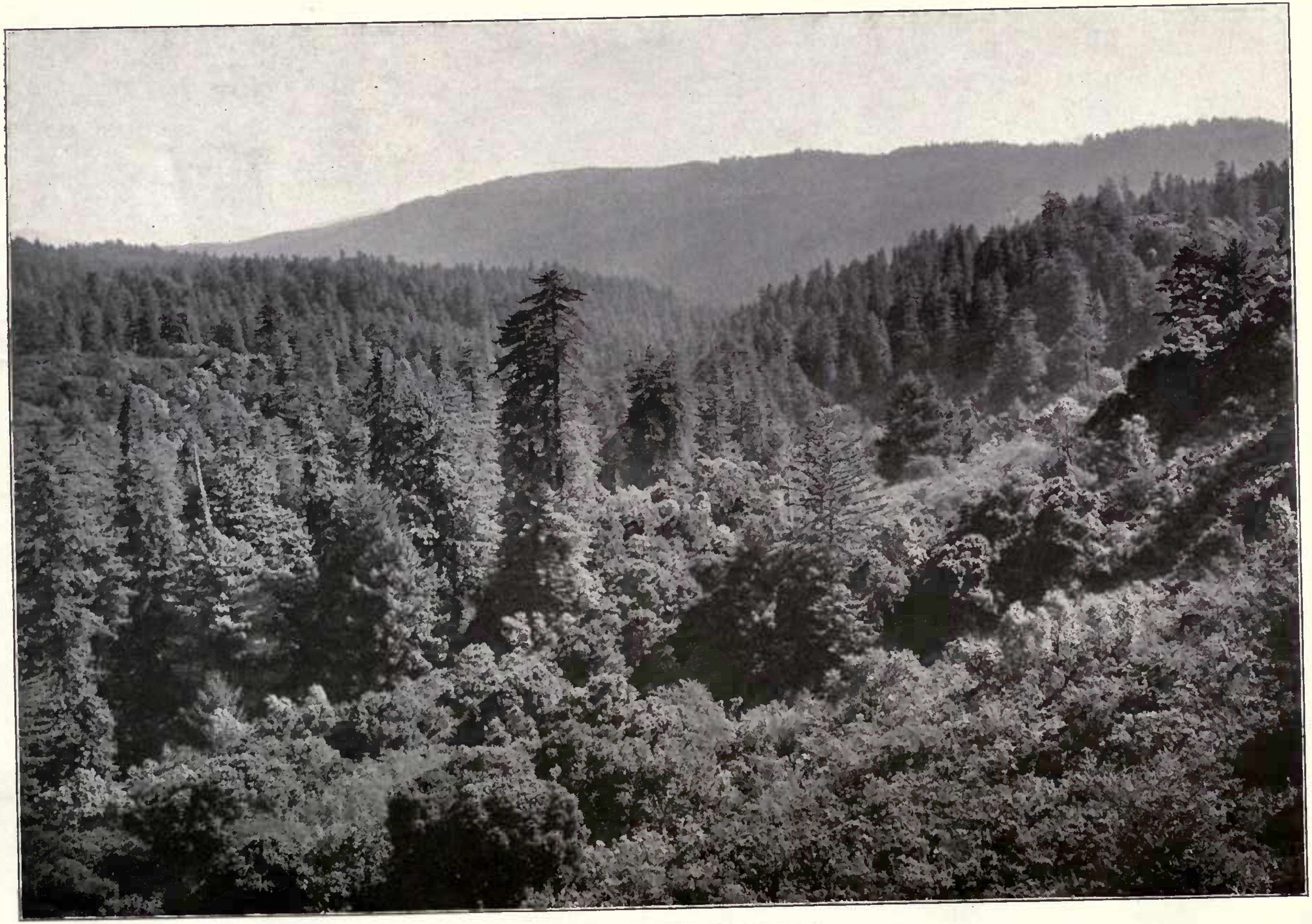
24. The whole Alameda system, therefore, including both the artificial and natural reservoirs, developed to its full capacity will be capable of conserving nearly all of the flow of the watershed. How far it will pay financially to go in conserving the "last drop" is another question, but it will clearly be practicable to go as far as your Company has ever claimed. It will not be extravagant to estimate that 85 to 90 per cent. of the run-off can be conserved without going to disproportionate expense. In this connection it should be noted that the Spring Valley Water Company owns or controls practically all the lands involved in the development of the system except the exposed gravel area in the vicinity of Livermore.

Long Periods of Drought.

25. Before passing from this subject I desire to note a criticism by Mr. Freeman (Freeman, p. 189) which at its face value appears to be well taken. He picks out a certain period of eight consecutive dry years and shows from the record that if *all* the run-off of the watershed had been saved and utilized it would have amounted to less than 62 m. g. d. But this period of detention, he says, would be longer than has ever been followed in practice, meaning, apparently, that prior storage could not be counted on to bridge over so long a period. This cannot be admitted. From Appendix C it appears that if the proposed general reservoir system had been in existence and had been only two-thirds full at the beginning of this period, it would alone have added nearly 50 m. g. d. to the supply for the entire eight years Add to that the natural draft from all other portions of the system and a total of at least 150 m. g. d. will result even for this period of unprecedented drought and without any resort to the artesian and San Joaquin sources to be referred to further on. If it be a rule of "world wide application" not to go beyond the yield of the two or three driest years in estimating a water supply, an exception must be made in a region like California where the aim must be to conserve and equalize *all* flow so far as physically and financially possible. No limitation to three, five or any other number of years can be admitted, but only to man's ability to conserve the flow.

26 Mr. Freeman objects to long depletion of reservoirs because of the vegetable growths that take place on the uncovered margin (Freeman, p. 187). I think that any one who takes the trouble to examine these uncovered margins, whether on Lake Chabot or the Peninsular reservoirs, will not worry much over that danger. The vegetable matter thus brought into the water is but a trifle to that leeched from the watershed during the winter rains. Moreover, no prohibitive expense is involved in artificially clearing off the growths in the few places where they accumulate to an objectionable degree. *There must be placed no limit* to the fluctuation of these reservoirs, just as Mr. Freeman places none on Hetch Hetchy except for the purely artistic consideration of preventing the floor of the valley from losing the appearance of a lake.*

*Long Valley Reservoir on the Los Angeles Aqueduct is designed to "provide against a series of dry years," according to the report of the consulting engineers, Freeman. Stearns and Schuyler. Based upon past run-off records there will be periods as long as fourteen years when it will be continuously below the flowage line.



IN THE COAST STREAMS SYSTEM.

Its Densely Forested Watershed Lends Valuable Aid in the Conservation of Its Very High Rainfall. Within a Two Hours' Ride of San Francisco. These Waters Will Be Diverted Into Crystal Springs Reservoir.

The Coast Streams System.

27. Your Company has acquired lands and water rights on the San Gregorio and Pescadero creeks, which, like the Pilarcitos of the Peninsula system, discharge into the Pacific Ocean. Much reliance has been placed upon the future potentiality of this system. It has been rejected by Mr. Freeman in his elaborate report just finished and he dismisses the whole subject in three brief paragraphs (Freeman, p. 96) in which he says among other things that "the gagings of stream flow of the Pescadero and San Gregorio are utterly insufficient to form a dependable basis for estimating the quantity they could supply."

28. I can find no justification for this summary dismissal of an important available source of water supply. Possibly it is based upon Mr. Grunsky's report (Freeman, p. 81), but if so the report should be made public. In the absence of something more substantial than the treatment given in Mr. Freeman's report, it must be accepted that Mr. Schussler did not make a mistake in advising his Company to acquire properties on those streams, and that he knew what they were getting in water supply resources.

29. In fact, there can be no reasonable doubt that the yield of these watersheds averages practically a million gallons daily per square mile. If there had never been a stream gaging or rainfall record taken there we could still proceed with perfect assurance up to the limit of supply which the Company has claimed. The habits of these Coast streams are thoroughly understood. Nearby is the Pilarcitos watershed with a careful record of many years from which we know both the annual yield and its distribution. The San Gregorio and Pescadero are undoubtedly quite as prolific water producers and their low water flow, both seasonal and cyclic, seems to be better sustained. As a matter of fact rainfall record covering a period of 17 years at a central point in the proposed development has been taken and it fully confirms this conclusion. Mr. Schussler's estimate of the average annual yield of the 60 square miles of water shed which the Company proposes to develop must be accepted as conservative in the absence of positive proof to the contrary.

30. The question of doubt relates to the practicability of conserving the flow. Mr. Schussler, with the same personal study which he devoted to the Peninsular system and by use of the same methods, devised a scheme for diverting a portion of the run-off through a long tunnel directly into the enlarged Crystal Springs reservoir, and of storing the balance in a large reservoir on the lower Pescadero from which it may be pumped as needed into the diverting tunnel and thence into the main distributing system. Captain Powell, who visited the watershed and examined the damsite, regards the latter, so far as could be determined by superficial inspection, as favorable for a great dam as the Calaveras or Crystal Springs sites and more favorable than the Lake Chabot site proposed by Mr. Freeman. The capacity of the reservoir can only be approximately estimated until a careful survey is made; but from a study of the U. S. G. S. sheets it is apparently 25,000 m. g.* The diverting dams and tunnel are of course practicable, and their cost is known within narrow limits.

31. While, therefore, precise data are not available, enough is known to give substantial justification to the Company's claim of dependable yield of 50 m. g. d. from this source (see report by Captain Powell. Appendix D; also Appendix G of Herrmann Report).

Artesian Supplies.

32. Situated as a large part of Greater San Francisco is on a vast artesian bed where water can be pumped in immense quantities and at low cost, subterranean water will continue for an indefinite period to be an important source of supply. Recognizing this, the Company long since began the acquisition of lands favorably situated for the development of a ground supply and now owns extensive tracts in the Santa Clara Valley at the head of the Bay. The development of these properties, whenever it takes place, will most likely be for use of the communities in the immediate vicinity. This would tend to avoid possible legal complications from transferring the waters elsewhere and would probably furnish a cheaper supply than would be possible from the main system. In any case, it will serve as a resource to diminish the demands upon that system. Its possible capacity cannot be accurately estimated, but on the basis of experience in similar situations nearby, the Company's estimate of 20 m. g. d. is conservative.

*A recent stadia survey made under Mr. Herrmann's direction indicates a capacity of 30,000 m. g.

CRYSTAL SPRINGS RESERVOIR.
The Future Capacity of this Reservoir is 63,000 Million Gallons. Note that at End of Dry Season this Reservoir is Practically Full.

The Coyote System.

33. I shall no more than refer to this source of supply here, as I have had no time to investigate it. The Company claims that it has a capacity of 20 m. g. d. aided by surface storage to the extent of 10,000 m. g. d. (Herrmann Report, Appendix F). The location is 63 miles southeast from San Francisco. The Company has acquired large holdings there.

The San Joaquin Source.

34. In Mr. Schussler's carefully wrought out scheme, as set forth in his report, ultimate resort to the San Joaquin—only 25 miles from the Arroyo del Valle reservoir or head of the Livermore gravels—is contemplated, his idea being to draw upon that source during the period of heavy spring and summer flow from the mountains and with it to supplement the storage of the system which, by that time of year, would have gathered up the great bulk of the local yield from the winter rains. It would also be practicable, if found desirable, to filter these waters through the Livermore and Sunol gravels. The details of the project, so far as worked out by Mr. Schussler, seem to be thoroughly practical, but there is no reason to give them extended consideration here. Resort to this source of supply will not be necessary for a long time, perhaps forty or fifty years, to come. The Company has never taken any active steps in its development as it has in the others hereinbefore considered. It has acquired no lands in connection therewith. No direct financial interests are involved and nothing in the future development of that source is at stake whatever may be the action taken in regard to other parts of the system.

The System as A Unit.

35. The characteristic feature of the Company's supply system—the one which makes it almost unique among city water supplies—is the complete unification of several independent sources into a single combination. More than 700 square miles of watershed, in widely separated situations, are made to act as a unit, as if all came from a single stream. By improving natural opportunities there will be developed around the Bay a maximum storage capacity of not less than 210,000 m. g. The wide distribution of storage sites with capacious inter-communication is an almost certain insurance against catastrophe by earthquake, fire, flood or war. Appendix C with accompanying map shows the distribution of these reservoirs and their several capacities. Whatever may be the ultimate source resorted to—the Coast Range or the Sierra—this magnificent storage system should be built as a guaranty against possible disaster. Time and experience will demonstrate the best method of using it, but it should always be considered the mainstay of the system.

36. A single pipe line of great length is a perilous reliance.* The recent experience of Seattle illustrates this. Last year a heavy flood suddenly ruptured the supply line and the city had only enough notice to fill pans, boilers and bath tubs before the mains were empty and for a week the citizens might be seen with pails, barrels and water carts getting water where best they might. Good fortune saved the city from a conflagration. Of course this particular accident will not happen again, but nature always strikes where least expected. With a great storage supply like that of San Francisco, no matter where she strikes, the cities will be safe. Particularly important is such a reserve with a very distant supply like that from the Sierra.†

Adverse Rights.

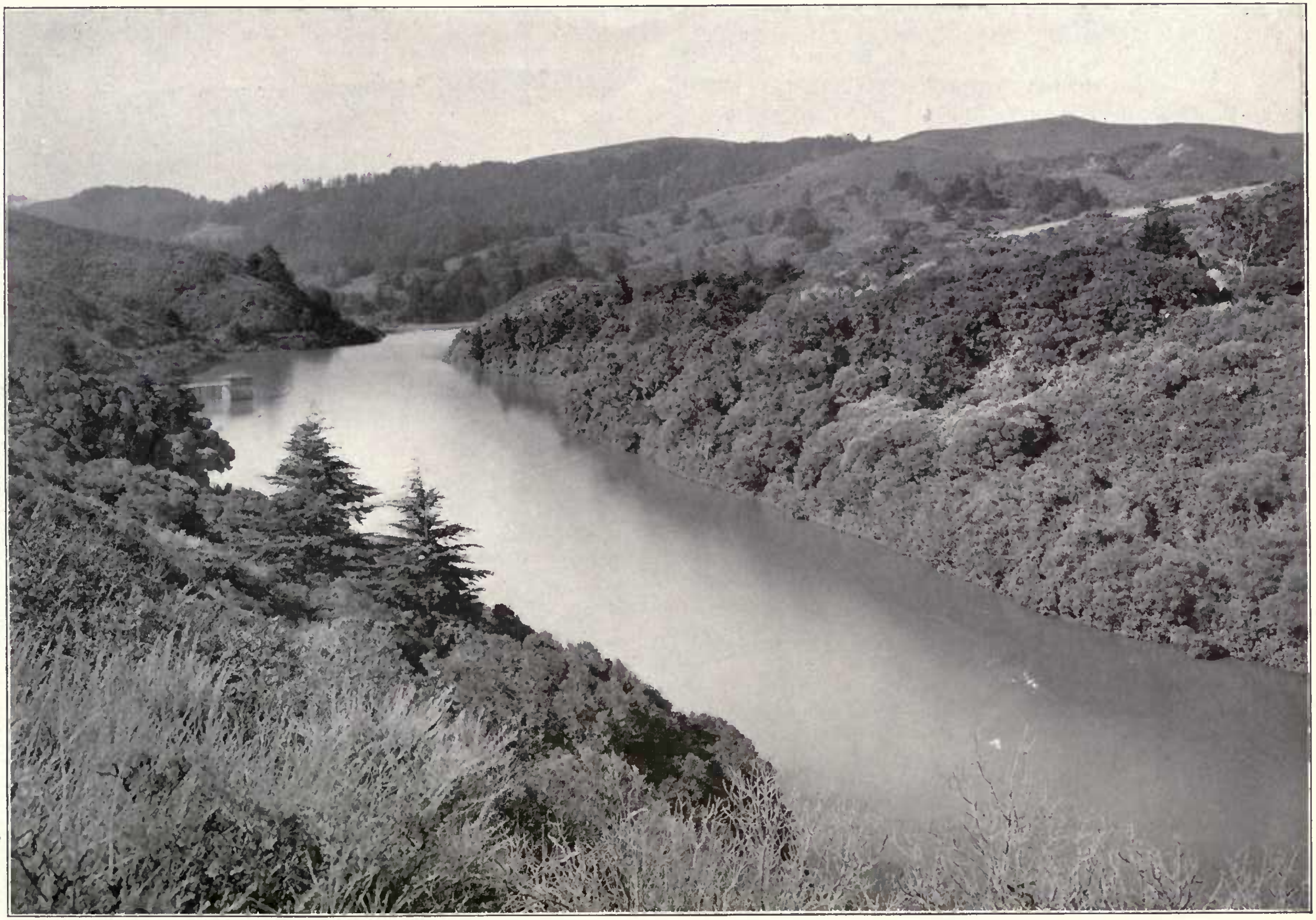
37. Great stress is laid by Mr. Freeman on the probable adverse legal rights which may interfere with the development of the Company's plans. In regard to this it may be said:

38. That every instance cited is of an indefinite, inchoate character—a possiblity only—a bridge that may never have to be crossed.

39. The argument does not affect in the slightest degree the physical problem of water supply. The supply is there whether controlled by the Spring Valley Company, the Bay Cities Company, the Niles Cone, or the Livermore farmers. It will all be used for local consumption and will ultimately drift mainly into unified control. In fact the very consolidation of the Bay cities into a single metropolitan water supply district, which Mr. Freeman rightly so much desires, will greatly hasten this consummation.

*The same remark applies to a double pipe line where both pipes are in close juxtaposition.

†It seems that an error in calculation has led to placing too great dependence in this respect upon the proposed San Miguel distributing reservoir in the City of San Francisco. (Freeman, p. 62.) "Four and a half months" (135 days) should apparently be 13.5 days.



PILARCITOS RESERVOIR AND WATERSHED.
This is the Largest Water Producer Per Square Mile of Watershed Area. Note the Similarity to Coast Streams Watershed Which it Adjoins.

40. The Company positively denies any validity to the greater part of these protests. There is no legal obligation that requires it to send down through Niles Canon all the flow of the Alameda watershed under 30 m. g. d. It would be quite impossible to prove that the replenishment of Niles Cone is dependent upon that precise amount of water from above the Sunol. The quick absorption of rainfall on the Cone itself, the heavy wash from the surrounding hills, the entire run-off of at least 12 square miles between the Niles and Sunol dams, and the fact that the Coyote hills cut off a considerable area from the Alameda waters which Mr. Freeman has classed as part of the Cone, all illustrate how uncertain these conditions are. The people of Niles Cone will reap greater benefit from relief from the Alameda floods by means of the artificial storage of its waters than they are likely to suffer loss from this imaginary restriction of supply.

41. It is probable that the Company, or its successor, the municipality, may from time to time have to make compensation for demonstrable damage. But with a wise and generous policy in these matters no great difficulty will be encountered. The cost will be a mere bagatelle in the entire cost of the system. The Company has fortified its position everywhere with remarkable foresight and the much talked-of legal obstacles to the development of its system are largely a bugbear.

Salvage of Soap.

42. The one valid argument that I have been able to discover in the mass of data arrayed against the Spring Valley system is that its water is harder than that of the Hetch Hetchy and will cause a greater outlay for soap. It is admitted that hygienically the water is of "exceptional purity." It is not even hard in a pronounced sense but simply harder than some other water. All this may be admitted and I shall make only three observations concerning it.

43. So far as the use of water in drinking is concerned, the sparkling crystal product from the Sunol Water Temple would be preferred on any table to rain or snow water.

44. In the use of soap it is not wholly correct to assume that hardness increases consumption. The more agreeable action of soft water on soap naturally leads to freer personal use whether necessary or not. In laundry work the case is doubtless different, but in any event, the attempt to capitalize the handicap of hardness in Spring Valley water is subject to so much assumption that it is not entitled to very weighty consideration.

45. San Francisco water compares favorably in respect to hardness with the average supplies of the country. Moreover, the water will improve in this respect with the development of the system. The present hardness comes mainly from the subterranean supply, now nearly 40 per cent. of the whole. The expansion of the system will reduce this proportion of ground water to 10 or 15 per cent., while the greater use of the gravels and the more frequent change of the water upon them may gradually reduce the hardness of the subterranean supply itself.

Comparison with Other Cities.

46. Reference is made in Mr. Freeman's report to the examples of Seattle, Portland and Los Angeles. It is important to point out the difference between the situations in those cities and that in San Francisco. Seattle went to its nearest source—nearer to the city than the Alameda system is to San Francisco. It is found in mountains most of which are no higher than those of the Coast Range, particularly around Mt. Hamilton. The supply is soft and pure but subject to muddiness whenever there are heavy rains. The cost of bringing this water to the city was only about $2,500,000.

47. Portland went to a comparatively nearby source of supply (30 miles), but little farther removed from the city than are the Peninsular sources of San Francisco supply. The cost of this work has been about $5,000,000.

48. Los Angeles, which is the chief precedent relied upon, undertook its great project from sheer necessity. It was a question of destroying vast irrigation developments in order to secure additional ground water supply, or of going to the mountains. There was no copious supply available as with San Francisco, and the two cases are in no sense parallel. Moreover, with its system of development containing such large lengths of open ditch it is wholly doubtful if this mountain supply will compare in purity with that which San Francisco has at its own

doors. The cost of the project will be about \$25,000,000. It has certain features apart from domestic supply which will be revenue producing and thus in part justify the outlay, but it is not likely that Los Angeles would have assumed this enormous burden if she had had a copious supply near by like that of San Francisco. Relative cheapness in the first two examples and absolute necessity in the third make all of them inapplicable as precedents for San Francisco.

49. San Francisco's supply is already in the strictest sense a mountain supply, but it comes from the Coast Range instead of the Sierra. Most of the topography is too rough and precipitous for agricultural use and a large part is densely timbered. Considerable tracts still belong to the government. A vast majority of the citizens of San Francisco undoubtedly have no conception of the extremely rugged character of most of these watersheds nor of their adaptability to the purposes of gathering water.

50. In the matter of scenic attraction, let those who are entranced by the beautiful pictures of the future Hetch Hetchy as drawn in Mr. Freeman's report (and they are not overdone) make an excursion through the Spring Valley properties, particularly in the Pilarcitos Valley, and they will find an exquisite beauty of scenery such as very few localities enjoy. The future development of the system is full of magnificent possibilities in this respect—possibilities that would be enjoyed by a thousand to every one who might visit the Sierra.

51. Because of the general roughness of the country, and particularly of the ground on which the City of San Francisco is located, the cost of delivering water under proper pressure to all portions is necessarily much greater than where the water can be pumped from an inexhaustible nearby source under practically uniform heads for the whole city, as in Chicago and Buffalo. The serious feature of this Sierra proposition is the large addition which it will make to a cost of service already unavoidably high.

The Spring Valley development involves no such increase. It can be taken up gradually in strict conformity to growing needs. But the initial cost of the Sierra project will be so great that *the interest alone will suffice for the permanent development of the Spring Valley system.** These are matters which the rate payer and the tax payer should candidly consider whatever may be their desires under the enthusiasm of the moment.

III.

SUMMARY OF CONCLUSIONS.

52. There is no substantial reason to believe that the consumption of water in San Francisco county will exceed 92 m. g. d. by 1950, or 235 m. g. d. for the five Bay counties, apart from the supply from private wells.

53. The three main divisions of the Spring Valley system—the Peninsula, the Alameda and the Coast streams—by careful development into a single unified system—are capable of a dependable supply of over 200 million gallons daily.

54. By resort to the Company's other sources and to the San Joaquin River, the supply may be indefinitely increased.

55. So far as *quantity* is concerned there is no present *necessity* for a resort to the Sierra, and will not be for an indefinite period to come.

If there were no Sierra, San Francisco could still face the problem of a future water supply with perfect equanimity.

56. As to *quality,* the Sierra supply is softer, but hygienically no purer and is less palatable as drinking water, than the Spring Valley supply. The extra cost of the Hetch Hetchy system will virtually be the price paid for a gain in the quality of softness.

57. Whatever source is ultimately adopted, the great reservoir group proposed by the Spring Valley Water Company should be made the mainstay of the system as a certain insurance against disaster.

IV.

PERSONAL STATEMENT AS TO HETCH HETCHY.

58. Concerning the Hetch Hetchy project I desire that my attitude shall be made clear, and

*Mr. Freeman seems to have had this thought in mind on page 69 of his report, where he says: "It is plain that there would be a saving in cost from developing these reservoirs (the Calaveras, San Antonio and del Valle), the dams of which are relatively inexpensive and which would put off for a few years the paying of interest on the large sum of money involved in building the Hetch Hetchy dam and the aqueduct easterly from Valle." And again, speaking of the Antonio and del Valle reservoirs, he says that their construction would permit the Sierra project to be "deferred four or five years and an amount would be saved in interest that would build the dams two or three times over."

so stipulated in my arrangements with you when I undertook this work. You explained to me at the time that it was not the purpose of your Company to antagonize the Hetch Hetchy project, but solely to defend your own system, and that what you wanted was an impartial analysis of the data in your possession by engineers entirely disassociated from local influences surrounding the problem.

59. I was a member of the Government Commission in 1904 which fixed the present boundaries of the Yosemite National Park, and as a result of my observations at that time I came definitely to the conclusion that the storage and proper utilization of the waters of that region is entirely consistent with the preservation of its natural beauties. This I believe to be emphatically true of the Hetch Hetchy Valley, and it is my judgment that such utilization of that valley is perfectly possible of realization, not only without detracting from its natural beauty, but possibly by adding materially thereto. Therefore, whenever necessity shall arise for such storage, I think the government should have no hesitation in granting the privilege under proper restrictions.

60. The project itself is admittedly a most attractive one. It is going to the ultimate sources of supply where nature has created great reservoirs in the perennial snow drifts of the mountains and has thus supplemented man's efforts at further storage by artificial reservoirs. To find these sources in a region which will be protected for all time by Federal supervision, to carry the supply to the heart of the metropolitan district and deliver it in its native purity to the homes of the people, all appeals very strongly to the imagination. It seems simplicity itself compared with the existing complex system which many find it difficult to understand. Mr. Freeman has shown a comprehensive grasp of the problem and his advice that, if the city is going to the Sierra, it go there on the basis of requirements for the indefinite future, is certainly wise.

61. The question discussed in the foregoing report is not that of the sufficiency or desirability of the Hetch Hetchy supply in itself, but that of the present necessity of such an outside supply for the people of San Francisco and vicinity. The result of the investigation has been to show that such a necessity does not now, and possibly may never, exist; that the supply would be in the nature of a luxury rather than a necessity and a very costly luxury at that.

62. If this finding is correct it involves a question of public policy of fundamental importance. The backbone of California's greatness is the agricultural development of her great central basin—a development impossible without water. Its claim upon the mountain supply is a pre-eminent one. Metropolitan needs are perhaps supreme, and if San Francisco had no other supply, the claims of the irrigable lands of the San Joaquin Valley, even those which already have priorities of flow, as the Turlock and Modesto districts, might have to step aside; but if it be a fact that the Bay cities have a supply near at home in the Coast Range that is amply capable of serving their needs, and if there be not enough in the Sierra for both, then it would surely be wrong to deprive the valleys of the only source of supply which is available to them. The rights of the existing irrigation districts are not alone to be considered, but the future demands of the San Joaquin Valley on both sides of the river.

Respectfully submitted,

H. M. CHITTENDEN.

Appendix A.

GROWTHS OF POPULATION AND WATER CONSUMPTION IN LARGE METROPOLITAN DISTRICTS OF THE UNITED STATES

By
H. M. Chittenden.

Table I (p. 25) is a statement of the growths of population in those metropolitan districts of the United States whose present population exceeds one million. The period considered is 1870-1910, except in the case of the New York district, which goes back to 1850. Areas were chosen large enough to eliminate the confusion of "annexation" in computing actual percentages of growth. From this table it will be seen that, except in the cases of New York and Chicago, the percentages of growth assumed below for San Francisco and Greater San Francisco are above the average of experience of other cities.

(Note Tables I, II, III, IV, on pp. 25 and 26.)

Statistics of per capita consumption of water are uncertain and unsatisfactory, and the extreme differences in cities in this respect can be understood only by a comparative study of all the conclusions.

Table IV, on page 26, is mainly compiled from replies received to inquiries addressed to the several towns.

Below are extracts from the opinions of the water works superintendents as to future per capita consumption.

Baltimore, Md.

With the increase of metered services a marked reduction in the per capita consumption is expected.

Buffalo, N. Y.

Enormous per capita consumption due to the fact that there are 30,000 houses owned or occupied by poor people who have no cellars, keep no fire at night in their kitchens in the winter and they must either let the water run or freeze. The per capita consumption in the future will not be increased.

Birmingham, Ala.

The per capita consumption in the future will decrease on account of the more extensive application of meters.

Chicago, Ill.

There will be a probable decrease in the per capita consumption for the coming years, depending, however, largely upon the policy adopted by changing administrations.

Cleveland, Ohio.

Increase per capita in 1910 over previous year due to increased business and an extremely dry and hot summer. In the future, however, the per capita consumption should be quite regular, as all services are metered.

Denver, Colo.

The per capita consumption will increase in the future, due to the increasing facilities for the use of water now being installed. Twenty years ago the only service connection to the ordinary dwelling house in Denver was a yard hydrant, and the number of bath-rooms, toilets, etc., was very much smaller than they are today; increase in the number of apartment houses, etc.

Detroit, Mich.

The business depression of 1896 had a marked effect upon the per capita consumption, causing a decrease. In 1904 there was an excessive consumption on account of a severe winter—people allowing water to run to prevent freezing. In 1910 great manufacturing enterprises cause of per capita consumption increase.

The increase in per capita consumption will continue with the increase of territory to be served and the coming in of manufacturing in-

TABLE I.

GROWTH OF POPULATION IN LARGE METROPOLITAN DISTRICTS OF THE UNITED STATES.

New York District—	Population 1910	Percentage increase 1900-1910	Population 1900	Percentage Increase 1890-1900	Population 1890	Percentage Increase 1880-1890	Population 1880	Percentage Increase 1870-1880	Population 1870	Percentage Increase 1860-1870	Population 1860	Percent Increase 1850-60	Population 1850
N. Y. County, N. Y.	2,762,522	34.7	2,050,600	35.3	1,515,301	25.6	1.206,299	28.	942,292	15.8	813,699	57.8	515,547
Kings County, "	1,634,351	40.1	1,166,582	39.1	838,547	38.8	599,495	42.7	419,921	54.0	279,122	100.9	138,882
Queens County, "	284,041	85.6	152,999	19.5	128,059	41.3	90,574	22.7	73,803	28.6	57,391	55.8	36,833
Richmond Co., "	85,969	28.3	67,021	29.6	51,693	32.6	38,991	18.0	33,029	29.5	25,492	69.2	15,061
Hudson County, N. J.	537,231	39.1	386,048	40.3	275,126	46.3	187,944	45.6	129,067	105.7	62,717	187.4	21,822
Total for District	5,304,114	38.7	3,823,250	36.1	2,808,726	32.2	2,123,303	32.9	1,598,112	29.0	1,238,421	70.0	728,145
Chicago District	2,405,238	30.8	1,838,735	54.2	1,191,922	20.1	607,524	73.5	349,966				
Boston District—													
Boston City	670,585	19.5	560,892	25.5	448,477	23.5	362,839	42.3	255,026				
Cambridge	104,839	16.0	91,886	30.1	70,028	32.9	52,669	32.8	39,634				
Chelsea	34,072	05.0	32,452	16.2	27,909	28.1	21,782	17.0	18,547				
Somerville	77,236	25.2	61,643	53.5	40,152	61.0	24,933	69.9	14,685				
Lynn	89,336	31.8	68,513	22.9	55,727	45.8	38,274	35.5	28,233				
Brookline	27,792	39.3	19,935	64.7	12,103	50.2	8,057	20.1	6,650				
Total for District	1,003,860	20.1	835,321	27.6	654,396	28.6	508,554	40.1	362,775				
Philadelphia Dist.—													
Philadelphia Co.	1,549,008	19.7	1,293,697	23.5	1,046,964	23.5	847,170	10.8	674,022				
City of Camden, N. J.	94,538	24.5	75,935	30.2	58,313	39.9	41,659	107.8	20,045				
Total for District	1,643,546	19.9	1,369,632	23.9	1,105,277	24.3	888,829	28.0	694,067				
Pittsburg Dist.—													
Allegheny Co., Pa.	1,018,463	31.4	775,058	40.4	551,939	55.1	355,869	35.7	262,204				
St. Louis District—													
St. Louis, Mo.	687,029	19.4	575,238	27.3	451,770	28.8	350,518	12.7	310,864				
E. St. Louis, Ill.	58,547	97.4	29,655	95.4	15,169	65.1	9,185	62.7	5,644				
Total for District	745,576	23.2	604,893	29.5	466,939	29.8	359,703	13.6	316,508				
San Francisco Dist.—													
San Francisco Co.	416,912	21.6	342,782	14.6	298,997	27.7	233,959	56.5	149,473				
San Mateo County	26,585	119.8	12,094	19.8	10,087	16.3	8,669	30.6	6,635				
Santa Clara Co.	83,539	38.7	60,276	25.4	48,005	37.0	35,039	33.5	26,246				
Contra Costa Co.	31,674	75.5	18,046	33.5	13,515	07.9	12,525	48.0	8,461				
Alameda County	246,131	89.0	130,197	38.7	93,864	48.8	62,978	15.9	24,237				
Total for District	804,841	42.8	563,395	12.2	464,468	31.5	353,170	64.2	215,052				

dustries. With the increase of metered service the waste would be reduced to a minimum and consequently the per capita consumption would be less.

Duluth, Minn.

Owing to a large percentage of service being metered, we expect a material reduction in the per capita consumption.

TABLE II

ASSUMED DECENNIAL PERCENTAGE OF INCREASE FOR THE NEXT FORTY YEARS IN SAN FRANCISCO AND GREATER SAN FRANCISCO (THE FIVE BAY COUNTIES).

Decade	San Francisco	Greater San Francisco
1910-20	25	30
1920-30	22½	27½
1930-40	20	25
1940-50	17½	22½

TABLE III.

FORECAST OF POPULATION AND WATER CONSUMPTION SAN FRANCISCO AND VICINITY

1910-1950.

San Francisco County			Year	Five Bay Counties		
	Probable Consumption				Probable Consumption	
Population	Per Capita in Gallons Daily	Total in Million Gals. Daily		Population	Per Capita in Gallons Daily	Total in Million Gals. Daily
417,000	85	35	1910	804,000	85	68
521,000	90	47	1920	1,045,000	92½	96
639,000	95	61	1930	1,333,000	100	133
746,000	100	75	1940	1,665,000	107½	179
877,000	105	92	1950	2,040,000	115	235

Grand Rapids, Mich.

We hope to reduce the per capita consumption in the future for the reason that a filtration plant is being installed. The cost of operating will greatly increase the cost of delivering water to consumers.

Kansas City, Mo.

Through a general installation of meters it is the expectation that the per capita consumption will be materially reduced and this reduction would result in a reduction of rates.

Los Angeles, Cal.

With the universal metering of services in 1903 the per capita consumption was reduced from 200 to 140 gallons. We do not expect that this rate will be materially reduced in the future in this city as its character as a residential place is permanent.

Minneapolis, Minn.

We find the increase in the consumption of water has been lessened by the installation of water meters.

Milwaukee, Wis.

We have sixty consumers that pay practically 50% of our water rates, which has a material bearing on our per capita consumption. We doubt very much whether the present per capita consumption can be reduced in the future for the reason that Milwaukee is a large manufacturing city.

TABLE IV.

PER CAPITA CONSUMPTION IN CITIES OF THE UNITED STATES.

Name of Town	Population in 1910	Per Capita Consumption in Gallons 1890	1900	1910
Baltimore, Md.	558,485	94	111	115
Buffalo, N. Y.	423,715	186	234	313
Birmingham, Ala.	132,685	200	...	123
Boston, Mass.	670,585	...	...	130
Chicago, Ill.	2,185,283	137	189	232
Cleveland, Ohio	261,353	106	168	101
Cincinnati, Ohio	364,000	...	115	125
Denver, Colo.	213,381	89	235	223
Detroit, Mich.	462,790	144	153	184
Duluth, Minn.	78,466	70	95	90
Grand Rapids, Mich.	112,571	73	135	142
Hartford, Conn.	110,000	...	...	68
Jersey City, N. J.	267,000	148	142	169
Kansas City, Mo.	248,381	...	60	98
Los Angeles, Cal.	319,198	...	...	140
Louisville, Ky.	224,000	...	...	99
Memphis, Tenn.	131,000	...	88	103
Minneapolis, Minn.	301,408	78	93	74
Milwaukee, Wis.	373,857	109	83	114
Nashville, Tenn.	110,364	138	140	112
New York, N. Y.	2,772,000	95	121	119
New Orleans, La.	339,075	...	...	274
Philadelphia, Pa.	1,549,000	...	221	203
Pittsburgh, Pa.	533,905	...	...	274
Providence, R. I.	224,326	48	54	63
Portland, Oregon	207,214	203	...	83
Rochester, N. Y.	218,149	62	85	91
Seattle, Wash.	237,194	...	70	100
St. Paul, Minn.	215,000	...	45	60
Spokane, Wash.	104,402	...	215	287
San Francisco, Cal.	416,912	...	75	85
St. Louis, Mo.	687,029	73	110	110
Washington, D. C.	331,069	...	210	180

Nashville, Tenn.

As the percentage of metered consumers increases the per capita consumption will decrease.

New York, N. Y.

Not until all services are metered will the wastage and leakage problem cease to be one of great moment in this city.

Careful inspection for wastage, maintained systematically without relaxation, with the enforcement of penalities for serious infractions of the regulations of the water department are nearly as efficacious as meters in restricting wastage and have the same result, viz: to prevent waste, but not use.

New Orleans, La.

With better living conditions and facilities for the use of water an increase in per capita consumption is expected. However, as half the houses in the city which would use least water are not supplied, a material reduction per capita is evident when all the houses are supplied.

Philadelphia, Pa.

The per capita consumption in the future, as in the past, will vary from year to year, according to the atmospheric heat and cold, to the head maintained in the several supply districts and to the efforts to prevent the waste of water. I do not anticipate an increase in the per capita until facilities are provided to increase the static head.

Pittsburg, Pa.

It is estimated that by complete metering the pumpage can be reduced to 150 gallons per capita per day, thus making possible a reduction in the rate per 1000 gallons to 12 cents, bettering the present rate by 6 cents. A complete metering is contemplated within the next five years.

Providence, R. I.

The per capita consumption will probably increase, notwithstanding all efforts to prevent it. It is due to the increased extravagance in the use of water by both the consumer and the municipality.

Portland, Oregon.

The consumption per capita should diminish to some extent with the general introduction of meters, which will come in time.

Rochester, N. Y.

There will probably be no variation per capita.

Seattle, Wash.

The increase in metering tends to reduce the per capita consumption to a minimum.

Springfield, Mass.

Very little variation in the per capita consumption for the future is expected. With the increase in metered services it will perhaps diminish somewhat, but not to any great extent.

Spokane, Wash.

In 1909 and 1910 the actual consumption would have exceeded the pumping capacity had not consumers been placed under the strictest regulations. With metered services we find a less demand upon the water system.

We also find that the metering of water is a direct benefit to the consumer as a means of personal saving to him.

Washington, D. C.

Within the next three or four years all services will be metered, thus greatly reducing the per capita consumption.

St. Louis, Mo.

The chart shows a steady increase in the per capita consumption, due probably through a greater demand from manufacturing sources.

ORDINARY FLOOD DISCHARGE OVER SUNOL DAM.

At this Point, About One Mile Below the Water Temple, the Run-off of the Alameda System Discharges Over the Dam. Note the Velocity of Approach Shown by the Trajectory of the Curve.

Appendix B.

REVIEW OF DISCHARGE DATA OF ALAMEDA CREEK, CALIFORNIA, RECORDED AT THE NILES AND SUNOL DAMS IN NILES CANON

By

A. O. Powell, M. Am. Soc. C. E.

I.
TOTAL RUN-OFF.

The runoff from the catchment basin of Alameda Creek has been measured at the Niles Dam from 1889 to 1900 and at the Sunol Dam from 1900 to date.

The drainage area above the Niles Dam is 632 square miles and above the Sunol Dam, 620 square miles. The latter dam is located three miles upstream from the former. In the original tabulation the flow over the dams was obtained by recording the daily readings from marks placed where they would be convenient for the observer and computing the discharges by the Francis type formula. The value of the co-efficient "c" was fixed by the Chief Engineer of the Spring Valley Water Company, Mr. H. Schussler. To the volume thus obtained was added the quantity of water piped underneath or around the dams. All the piped water passed through the pumps at Belmont, where the quantity was measured by the strokes of the pumps.

The manner of ascertaining the runoff, as outlined above, has been criticised as crude, and the resulting quantities, unreliable and excessive. The volume of water that may be supplied by the Alameda system has of late become an issue and because of the reflection cast upon the record the data has been subjected to severe analyses by hydraulic experts of recognized high reputation. The purpose of this paper is mainly to review the detailed work of the experts and to compare their computations with the water company's original record.

A clearer understanding of the record will be had by a knowledge of its origin. The dams were built to facilitate the operations of the Spring Valley Water Company, and not to serve as measuring weirs. The engineer naturally proceeded to utilize them in securing such a record of the waste water as in his judgment would be sufficient for the requirements of the company. He knew that the measurements would not be precise, and at that time there was no desire for extreme accuracy; also that, as the dams were low structures, erected in a stream of wide fluctuation and steep slope, the back water and approaching velocity would complicate the form of the equation and the value of the coefficient. Furthermore, floods would alter the condition of the river bed and vegetation along the banks would influence the factors. Mr. Schussler relates orally that when the Niles Dam was completed he made float measurements to determine the value of a co-efficient in the simple weir formula that would give him conservatively safe quantities; probably ten or fifteen per cent under the true figures. The co-efficient selected was 3.24. For convenience the formula was rearranged to give gallons per day from linear measurements in inches as follows:

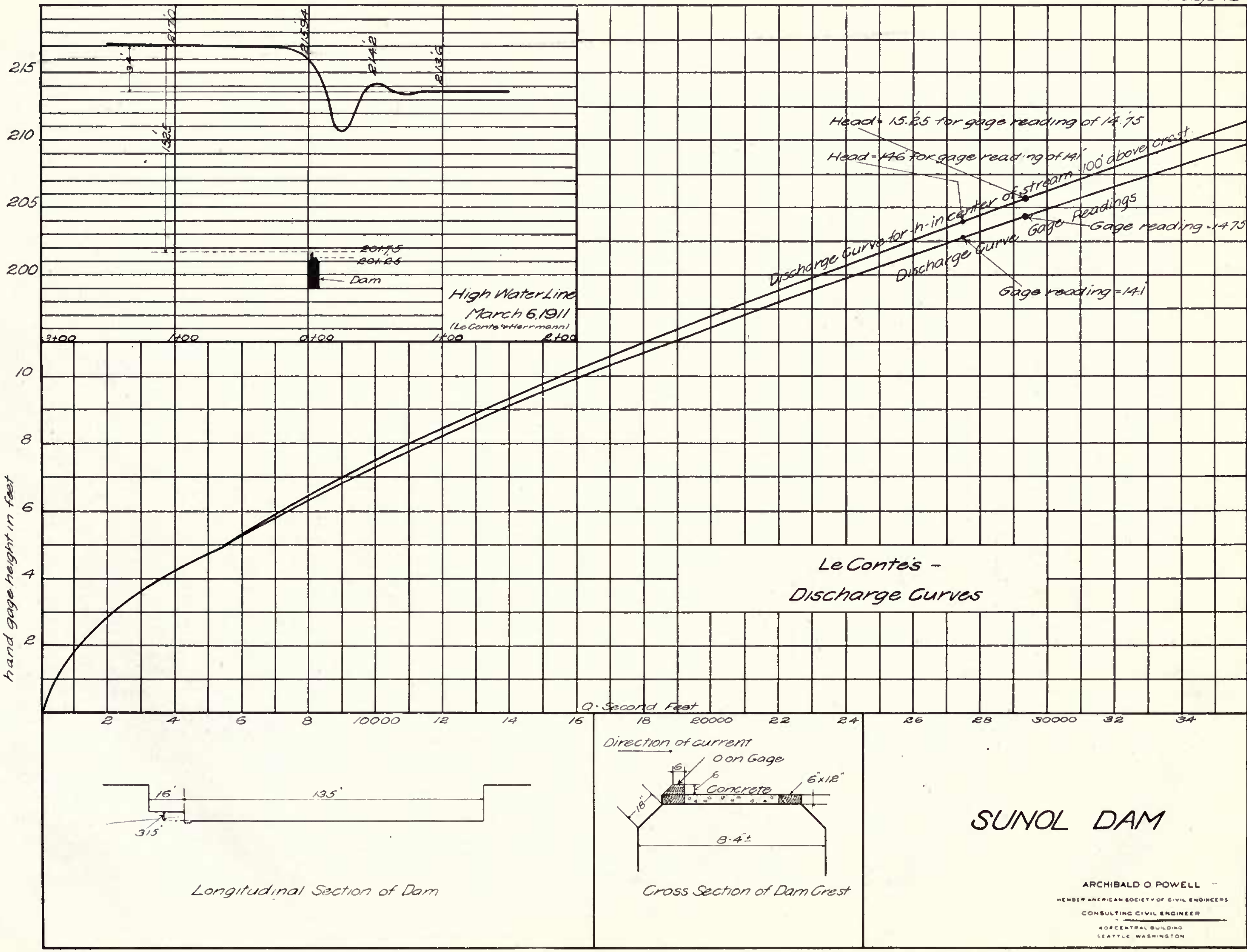
$$\text{Gallons in 24 hours} = 4200\ b\ (h)^{3/2}$$

Or expressed in cubic feet per second from linear measurements in feet:

$$\text{Cubic feet per second} = 3.24\ B\ (H)^{3/2}$$

"h" and "H" being the gage readings in inches and feet, respectively.

When the Sunol Dam superseded the Niles Dam, the engineer, following the same procedure


High Water Line
March 6, 1911
(Le Conte & Herrmann)
Dam
201.75
201.25
217.0
215.94
214.2
213.6
Head = 15.25 for gage reading of 14.75
Head = 14.6 for gage reading of 14.1
Discharge Curve for h in center of stream 100' above crest.
Discharge Curve. Gage Readings
Gage reading = 14.75
Gage reading = 14.1
Le Conte's -
Discharge Curves
hand gage height in feet
Q. Second Feet
10000
20000
30000
Longitudinal Section of Dam
135'
16'
3.15'
Direction of current
0 on Gage
Concrete
6"x12"
18"
8.4'±
Cross Section of Dam Crest
SUNOL DAM
ARCHIBALD O POWELL
MEMBER AMERICAN SOCIETY OF CIVIL ENGINEERS
CONSULTING CIVIL ENGINEER
404 CENTRAL BUILDING
SEATTLE WASHINGTON

as before established the formulae for that dam to be:

$$\text{Gallons in 24 hours} = 4400\ b\ (h)^{3/2}$$
$$\text{Cubic feet per second} = 3.40\ B\ (H)^{3/2}$$

No one can critically examine the work executed by Mr. Schussler during the two scores of years that he administered the Engineering Department of the Spring Valley Water Company without acquiring confidence in his judgment of facts and in his conservatism in estimating engineering matters pertaining to the conservation of the company's water supply, and will not be surprised to learn that investigations during the past summer have substantiated his claim to have under-recorded rather than over-recorded the runoff of Alameda Creek. A superficial examination of the situation will incline most hydraulic engineers to the impression that the Schussler formulae could not be far wrong, and that the error was likely to be on the safe side. Back water, unless exceeding two-thirds of the depth of the weir is not a source of special concern, and in the case of these dams when the back water rose above that percentage the effect would be neutralized by the approaching velocity due to a slope of .003+ at the Sunol dam (S. V. W. Co's profile) and .009± at the Niles Dam (Mr. Freeman's diagram, p. 181).

The first criticism upon the accuracy of the water company's tabulated flow arose from the publication in 1903, by the U. S. Geological Survey, Department of the Interior, of Water Supply and Irrigation Paper No. 81, entitled California Hydrography, by J. B. Lippincott. On pages 32-39 are given "Discharge Measurements of Alameda Creek, Alameda County." The purported discharges for the higher stages are so pronouncedly less than the computations by the water company, that there ensued speculation as to the cause of the differences. The report was prepared under the general direction of Mr. Lippincott, aided by a staff of field assistants and office computers who collected the data and did the routine work of tabulation. It was manifestly impossible for the chief to verify the field information secured by his force. Within the past month Mr. Lippincott has succeeded in locating the original note books of his assistants, and has discovered that a radically wrong section of the dam was used. Correcting the section, the Government's record does not materially differ from the company's. The erroneous sketch produced inconsistencies that undoubtedly caused the editors to say "the large flood measurements that have been computed contain elements of error". Mr. Lippincott, under date of September 28, 1912, filed with the Spring Valley Water Company, and with the Department, a frank letter setting forth the essential facts. It is unfortunate that the error should have occurred in a Government publication. The confidence that is reposed in official papers, may have prompted the engineers employed by the City of San Francisco to question the water company's record.

The first set of experts to specifically investigate the runoff data was a committee of engineers, Messrs. Marx, Grunsky and Hyde, who were appointed by the City of San Francisco at the request of Mr. Freeman, to scrutinize and report upon the record. The committee worked at the problem for a long period. The findings have not yet been made public, but it is persistently rumored that if the report is published it will not lessen the claims of the water company.

Subsequent to the committee's work, Mr. G. G. Anderson for J. G. White and Company, made an exhaustive and independent study of the subject and arrived at quantities that exceed Mr. Schussler's. Mr. Anderson's labors were followed by the investigations of Mr. Herrmann, the present Chief Engineer of the Spring Valley Water Company, who engaged Prof. Le Conte to conduct a series of experiments on models 1/19 and 1/20, the size respectively of the Niles and Sunol Dams. All the details of the dams, river and gages were reproduced as nearly as possible in an exceedingly interesting series of tests. Prof. Le Conte has applied the theory of hydraulics to the data secured from the experiments and established for each dam two curves of discharges with "head in feet" and "gage readings in feet", respectively, as arguments. Mr. Herrmann has computed the flow over the dam since 1889, from the observed gage heights and the Le Conte curves. The resulting quantities compare well with prior studies and are also in excess of Mr. Schussler's. In order to check the list, Mr. Herrmann applied two of the more recent published formulae to the flow over the dams during the flood of March 6-7, 1911, and also computed the volume by Kutter's formula

for the cross section and slope of the stream above the Sunol dam. The two formulae for dams and the Kutter formula for channel flow support the accuracy of the Le Conte curve.

The profile of the water surface above Sunol dam, during the flood of March 6-7, 1911, was surveyed by the Spring Valley Water Company a few days after the peak of the flood had passed. The elevations of the water surfaces at the stations were obtained from the water marks left on trees and on the banks. The profile below the dam was made in a like manner, but at a subsequent date.

The volume of the flood at its highest stage, as computed by Mr. Herrmann in the various manners, was:

on the dam is taken from Le Conte's curve of heads, measured 100 feet upstream from the dam and corresponding to the observed gage heights, and the backwater is taken from the Le Conte-Herrmann High Water Line, Sunol Dam, March 7, 1911 (see page 30). The gage reading for March 7 was recorded as 14.1′, equivalent to Le Conte's "h" of 14.6′, but it appears from the diagram of High Water Line, March 7, 1911, that "h" at the peak of the flood was 15.25′, corresponding, on Le Conte's curves, to a gage reading of 14.75′. The velocity of approach has been assumed at 10 feet per second, a trifle less than the mean velocity of the whole flow section of the creek 600 to 2000 feet above Sunol Dam. (See page 33.) The channel measurements have also been gone over, using the uniform slope between stations 6 and 20, and using a mean creek cross section derived in a different manner from that pursued by Mr. Herrmann.

CHANNEL MEASUREMENTS.

(Herrmann.)

Formula	n	Slope	Quantity
Kutter	.045 .040 .035	.003	30,900 cu. ft. per sec.

WEIR MEASUREMENTS—SUNOL DAM.

(Herrmann.)

Computed By	Author of Formula	Gage Readings Feet	Head in Feet	Backwater in Feet	Approaching Velocity in Feet per Sec.	Quantity
Powell	Schussler	14.6	....	....	....	27,718 cu. ft. per sec.
Herrmann	Molitor	14.6	15.5	12.3	12.0	26,700 " "
Herrmann	Bligh	14.6	15.5	12.3	12.0	31,000 " "
Herrmann	Le Conte	14.6	....	....	....	28,800 " "

The Sunol Dam was built 6 feet wide on top, with a 6″ x 12″ beveled timber laid flat on the upstream longitudinal edge. This timber was largely worn away by the gravel and stones carried by the high water, prior to the peak of March 7, 1911. Mr. Herrmann, in his treatment of the flood volume, assumed the timber to be all gone. He may have been right in doing so, but as the object of the determinations is to confirm the Le Conte curve, it was thought advisable to recompute the quantities with the same and some additional formulae, but conforming to the cross section of the dam as duplicated in the experiments and to the other data as interpreted by the writer. In the models, the 6″ timber was maintained intact. The zeros of the Schussler and Le Conte gage readings and Le Conte "heads" coincided with the top of the timber. The "head"

In the computations for channel flow the linear measurements were obtained by scaling, from a small blue print of cross sections furnished by the Spring Valley Water Company. The widths of each subdivision in each station section were scaled and the average taken as the width of that subdivision in the mean creek section. The depths for the mean creek section were obtained by scaling the depths for each 1/10 of the width of each subdivision in each section and averaging. The flow through the timbered east bank was neglected as probably a negligible quantity. The main channel and west bank were combined into one area. The mean cross section is shown on page 34. The area, wetted perimeter, hydraulic

radius, slope, "n" and "c" for the two divisions of the average creek cross section are:

A=	2,174.8	and 572.2	
w. p.=	147.73	" 132.3	
r=	14.72	" 4.3	
s=	.00375	" .00375	
n=	.050	" .050	Kutter
v=	11.91	" 4.94	"
c=	40.	" 40.	Exponential
v=	11.87	" 5.21	"
*m=	6.50	" 6.50	Bazin
v=	13.70	" 4.80	"

The recomputed volumes are shown below, and the diagrams are pages 30 and 34.

known as the Spring Valley Water Company's unrevised record) is conservative.

Gage readings were not taken simultaneously at the Niles and Sunol Dams; those at the former were discontinued when those at the latter were commenced, therefore the Le Conte calibrations for the two dams can not be compared with each other by observation records of the same flood. It would be instructive and convincing to make such comparisons, but in the absence of the necessary data equal credence must be reposed in Prof. Le Conte's experiments with both models. If the Sunol tests are accepted, the Niles tests must also be accepted, as the two series were made in identical manner.

CHANNEL MEASUREMENTS.
(Powell.)

Formula	Gage Readings in Feet	Head in Feet	n	m	c	Slope	Quantity
Kutter	14.75	15.25	0.050	...	...	.00375	28,730 cu. ft. per sec.
Bazin	14.75	15.25	.....	6.5	...	.00375	32,560 " "
Exponential........	14.75	15.25	.....	...	40.	.00375	28,800 " "

WEIR MEASUREMENTS.
(Powell.)

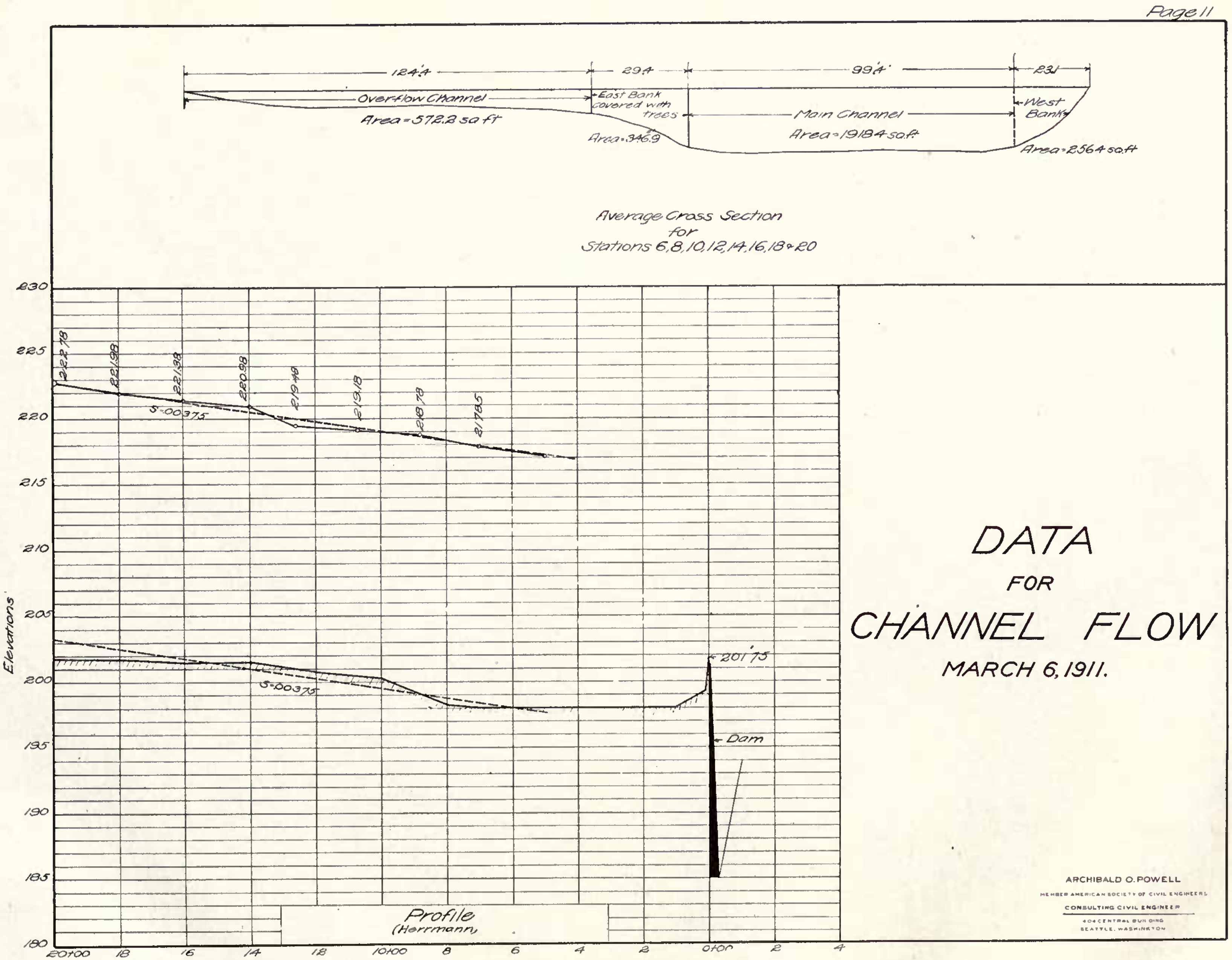
Formula	Gage Readings in Feet	Head in Feet	Backwater in Feet	Approaching Velocity in Feet per Sec.	Quantity
Schussler	14.1	....	....	...	26,552 cu. ft. per sec.
Bligh	14.1	14.6	11.2	10.	28,120 " "
Le Conte	14.1	14.6	....	...	27,500 " "
Schussler	14.75	....	....	...	28,150 " "
Bligh	14.75	15.25	11.95	10.	29,220 " "
Le Conte	14.75	15.25	....	10.	29,350 " "

The computations by Mr. Herrmann and by the writer fortify Le Conte's curves for the Sunol Dam, which are accepted as furnishing the closest approximations to the truth. Le Conte's curves in turn verify the statement of Mr. Schussler that his run-off record (now

*The value of "m" in the Bazin formula was found by projecting the line of known values to the degree of roughness corresponding to n=0.50 in Kutter's formula.

Objection has been made to the practice of basing the flow upon one gage reading taken at a fixed hour each day, but Mr. Herrmann has shown from an actual trial at the Sunol Dam that the daily errors balance each other in the course of a season.

The total run-off, 1889-1911 (flow over dam plus the Belmont pump), as determined by Schussler, Anderson and Herrmann-Le Conte, is:



CHANNEL FLOW OF ALAMEDA CREEK.

Year	Area of Drainage Basin in Sq. Miles	Quantity in Million Gallons Schussler	Anderson	Herrmann-Le Conte
1889-90...	632	153,634	184,476	165,907
1890-91...	632	36,590	42,359	38,931
1891-92...	632	19,348	21,574	20,905
1892-93...	632	102,039	119,642	117,511
1893-94...	632	55,638	72,539	59,202
1894-95...	632	81,565	98,232	86,422
1895-96...	632	37,231	43,255	39,967
1896-97...	632	63,825	75,351	67,771
1897-98...	632	3,732	3,951	4,498
1898-99...	632	24,623	25,923	23,091
1899-00...	632	14,960	20,052	19,085
1900-01...	620	31,828	42,124	40,038
1901-02...	620	19,793	29,146	30,861
1902-03...	620	23,199	39,698	37,854
1903-04...	620	37,771	35,414	36,464
1904-05...	620	20,254	20,017	20,451
1905-06...	620	63,134	62,728	67,662
1906-07...	620	102,917	105,581	104,856
1907-08...	620	21,189	20,473	20,703
1908-09...	620	83,989	82,130	79,470
1909-10...	620	33,949	31,156	32,025
1910-11...	620	74,852	92,004	92,425
Yearly average....		50,275	57,628	54,823
Daily average.....		137.7	158.0	150.2
1911-12		.....	11,065	10,937
Yearly average....		.....	55,604	52,915
Daily average.....		.....	152.3	144.9

The yearly quantities in preceding table are for seasonal years ending June 30. In past publications the yearly runoffs prior to 1904-5 were assembled by calendar years, hence the change will show a slight difference in yearly distribution. Strictly speaking, a correction should be made in the first ten years' record for the extra 12 square miles of drainage area. No effort will be made to do so. It is not a momentous matter and the writer has no desire to invade the realm of speculation as to the proportionate runoff of the smaller area.

The conclusion is inevitable that the original runoff record as kept by the Spring Valley Water Company in accordance with Mr. Schussler's method is below the true figures. As previously stated, the Herrmann-Le Conte result is deemed to be the most accurate because it is based upon scientifically applied experiments.

II.

DEPENDABLE RUNOFF.

The proportion of total runoff that may be conserved can not be stated with exactness. Engineers, however, are required to investigate such matters and to give opinions based upon data which is not as complete as could be desired. Such problems should be approached with an open mind as a predilection or prior bias may unconsciously warp the judgment of the best men. This is strikingly illustrated in the reports on the Alameda Creek System, for on no other hypothesis can the extremely divergent views be explained.

There are four facts about which there should be no dispute, i. e., area, topography, total runoff and rainfall. The first two are agreed upon. The latter has been thoroughly probed by three engineers acting independently, and a close agreement reached by all. The variations in the location of isohyetose lines are no greater than might be expected under the circumstances. The third (total run-off) has been attacked by the opponents of the Alameda system. If they had applied the same painstaking analyses to the study of runoff as was given to precipitation there probably would have been a like agreement on the former element of the problem. The writer is convinced of the general correctness of the Spring Valley Water Company's revised runoff record (Herrmann-Le Conte). He also accepts the area, topography, and in general the rainfall distribution. With these four premises fixed, it should be comparatively easy to distribute the runoff to the sub-catchment areas. But here creeps in again the personal equation of the individual. The writer desires only to say that he has visited the locality, carefully studied the reports and is of the opinion that Mr. Anderson's treatment of distribution is scientific and logical. A perusal of the latter's report will be refreshing from its directness, conciseness and, considering the complexity of the subject, its simplicity.

Mr. Anderson maintains (as does also Mr. Herrmann) that the total run-off may be increased by preventing unnecessary evaporation in the Livermore Valley. He places the increment at 20 to 24 million gallons daily and increases the measured runoff by those amounts, making, according to his figures, 172 to 176 million gallons daily to be accounted for. By a reasoning from the data at hand, Mr. Anderson segregated the flow for the entire system during the past 23 years, as shown in the following condensed table:

TABULATION OF SEGREGATED FLOW

(Anderson.)

23 Years (1889-1912)

CATCHMENT. Name.	Area. sq. mi.	Yield in Million Gallons. Yearly Maximum.	Minimum.	Average.	Daily average.
Calaveras	100	67,000	3,000	23,543	64.50
Upper Alameda	34.6	23,182	750	6,165	16.89
San Antonio	38.7	14,900	450	3,743	10.26
Sunol	48.5	14,162	170	4,345	11.90
Arroyo Valle	138.3	31,054	1,200	11,469	31.42
Arroyo Mocho	48.4	6,534	0	2,262	6.19
Lower Arroyo Valle	6.9	885	0	258	0.70
Upper Livermore	32.7	4,230	0	1,234	3.39
Lower Livermore	24.4	3,180	0	928	2.54
Positas Creek	81.7	10,500	0	3,069	8.41
Tassajero	26.1	3,320	0	969	2.66
Alamo Creek	42.7	5,528	0	1,615	4.42
Total	....	....	....	59,600	163.28

The total of segregated flow falls short about 11 million gallons daily from the estimated average total runoff of 172 to 176 million gallons, including the evaporation loss, and indicates a substantial check upon the derived segregated flow.

Mr. Anderson has made an analytical demonstration of what portion of the total runoff might have been conserved in the past, if the Calaveras, San Antonio and Valle reservoirs had been built with capacities of 46,315*, 10,500 and 12,900 million gallons respectively, and if the Crystal Springs Reservoir had been enlarged (as it is proposed to do) to 55,000 million gallons. He allowed an evaporation loss from the reservoir surfaces of 48 inches annually. His summary is given below.

SUMMARY OF DEPENDABLE YIELD

Million Gallons Daily.

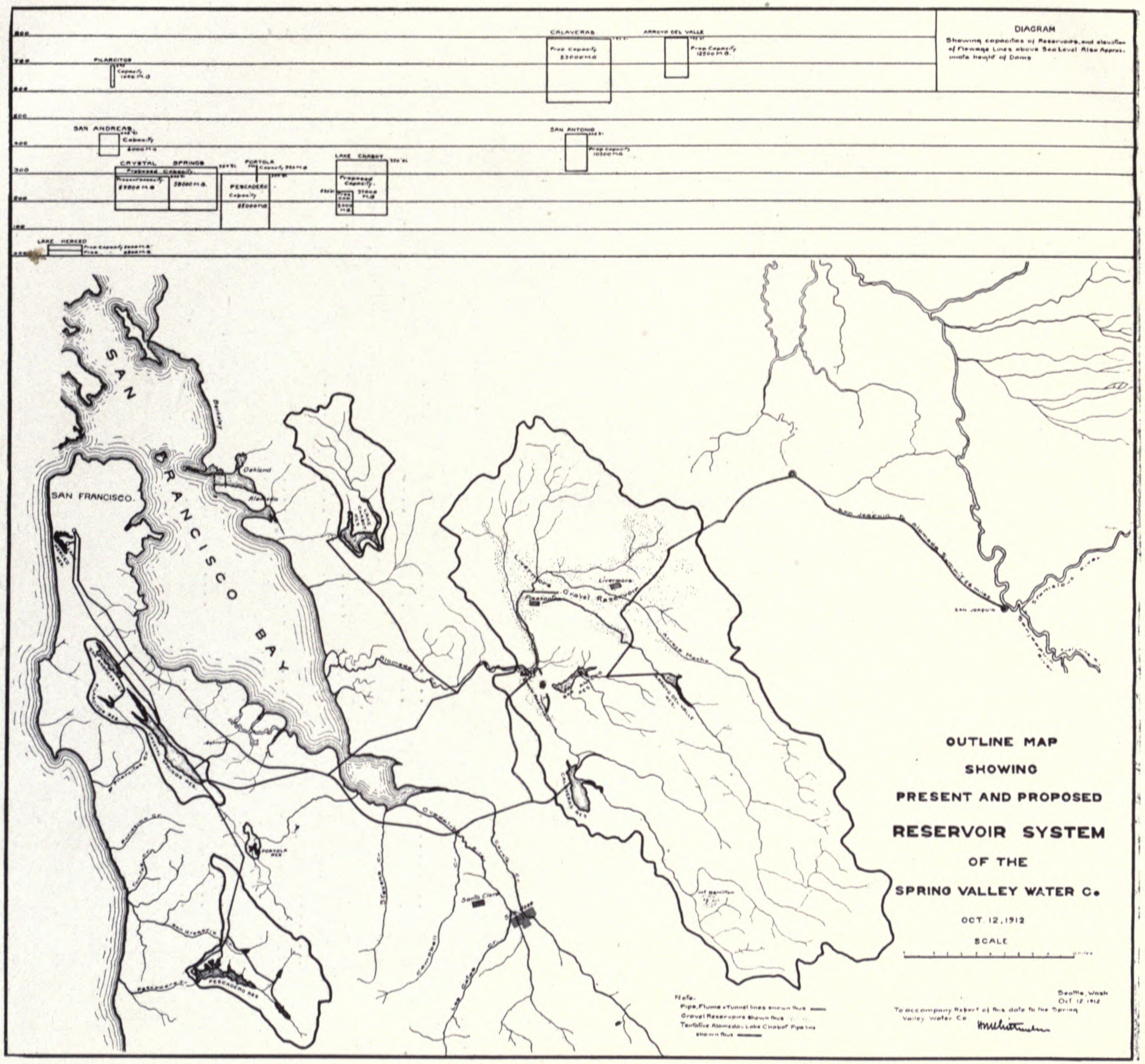
(Anderson.)

Calaveras Reservoir, direct	57.00
" " storage of surplus	9.48
San Antonio Reservoir	8.50
Arroyo Valle Reservoir	18.00
Sunol-Sinbad Creek Area	7.40
Livermore Gravel Reservoir	30.00
Evaporation in Livermore Valley	12.00
	142.38
Less for local consumption	2.00
	140.38

The amount of saving that may be effected by reducing evaporative losses in the Livermore Valley is an open question. It will be safer to ignore that possible source of additional supply and confine discussion to the more patent possibilities. The feasibility of controlling approximately 90 million gallons daily in the three reservoirs can be denied only on the theory that it is inadmissable to permit wide fluctuations in the level of the stored water which will leave the upper portions of the reservoir slopes uncovered for a period of 8 or 9 years. The objection holds true in some regions, but the similar operations of the Spring Valley Water Company's present reservoirs have not indicated any ill effects from that cause, therefore the fear of vegetable contamination may be dismissed so far as it relates to the territory in question.

The practicability of the Sunol and Livermore gravel reservoirs has been assailed, but absolute dependence can be placed upon the testimony of the highest authorities, like Dr. Branner and Messrs. Mulholland and Lippincott, that the reservoirs are a fact, and being there, it only needs the proper installations of pumps and conduits to develop them to almost any degree. It is the writer's judgment that the gravel reservoirs have capacities in excess of the supply from the watershed after excluding the catchment areas tributary to the three artificial reservoirs, and are also capable of filtering San Joaquin waters when it is desired to do so. The extent to which the gravel reservoirs may be put to use will be limited, not by their capacities, but by the cost. A yield of upwards of 40 million gallons daily from the gravel reservoirs is a moderate estimate. Adding this amount to the 90 million gallons daily from the artificial reservoirs will

*It is proposed to build Calaveras reservoir to a capacity of 55,000 million gallons by the construction of a dam to elevation 800, as recommended to the Spring Valley Water Company by Mr. Freeman.



OUTLINE MAP OF THE WATER SUPPLY OF SAN FRANCISCO.

give a dependable yield of more than 130 million gallons daily. This quantity may be augmented by drawing upon the San Joaquin River.

The character and extent of the works that will ultimately be constructed to secure the most efficient development of the system may differ quite widely from those heretofore suggested. The most that may be said of present plans is that they present one solution. It is conceivable that higher dams and more gravity pipes may prove economical.

A. O. POWELL.

Seattle, Washington, October 12, 1912.

Appendix C.

STORAGE RESERVOIRS EXISTING AND PROPOSED

THE SPRING VALLEY WATER COMPANY.

(Including also Lake Chabot in Oakland)

Name of Reservoir	Elevation above Sea Level	Areas in Acres Present	Areas in Acres Future	Capacity in Mil. Gal. Present	Capacity in Mil. Gal. Future	Remarks
Lake Merced	18	....	....	2,500	....	May possibly be abandoned.
Lake Merced	38	....	....	....	5,000	Enlargement proposed by Schussler.
Pilarcitos	700	125	125	1,000	1,000	
San Andreas	450	549	549	6,000	6,000	
Crystal Springs	288	1,500	....	23,500	63,000	Probable maximum enlargement.
Crystal Springs	343	....	....	....	....	
Portola	330	65	....	334	....	Will probably be abandoned.
Pescadero	400	....	....	....	25,000	Not built.
Calaveras	800	....	1,900	....	53,000	" "
San Antonio	450	....	656	....	10,500	" "
Arroyo del Valle	800	....	630	....	12,500	" "
Lake Chabot	235	435	....	5,000	......	Maximum practicable enlargement. (Freeman, p. 136.)
Lake Chabot	350	....	1,312	....	37,000	
Total, omitting Portola	...	....	....	38,000	213,000	

The numerous distributing reservoirs existing and proposed will probably bring the larger of these two totals up to 215,000 M. G.

COAST STREAMS WATERSHED.
Densely Wooded and Favorable to Large Productivity.

Appendix D.

REVIEW OF DEPENDABLE YIELD OF COAST STREAMS

By
A. O. Powell, M. Am. Soc. C. E.

The coast streams, so called, are the headwaters of the Pescadero and San Gregorio Creeks, two contiguous streams lying on the west side of the Peninsula Mountains and discharging into the Pacific Ocean. The center of the drainage areas that it is proposed to develop as sources of water supply for San Francisco is 36 miles south of San Francisco, and the north end of the area is separated by only 3½ miles from the south end of the Crystal Springs watershed. The region is rough, broken and mountainous, covered for the most part with a dense growth of inferior timber. It is very sparsely settled and because of the character of the topography, must always remain so. The danger of human pollution in the watershed is as remote as can be desired. As may be expected from the proximity of the ocean (10 miles distant) and from the sea side slope of the catchment areas on the first range of mountains, the rainfall is heavy. It will be evident to any person accustomed to estimating runoff that the selected watershed is a prolific water producer per square mile of area. Not only is the annual precipitation great, but the percentage of runoff is also large. The availability of the headwaters of the two streams for the purposes of the Spring Valley Water Company was early recognized, constantly kept in mind, but their development has been held in abeyance until after the Alameda Creek system had been exploited and until the demands for water made it necessary to add more units to the system. The coast streams being so close to the city of San Francisco and having been seemingly, though not actually, neglected by the water company, has misled the public into minimizing the potentiality of the district. No greater error, in the consideration of a metropolitan water supply, could be perpetrated, for, as a matter of fact, the two upper tributaries of the creeks are exceptionally efficient,—the best per square mile of all the territory controlled by the company. It is certain that any one charged with investigating the sources of a water supply for San Francisco, who fails to pay grave attention to the possibilities in the Pescadero and San Gregorio creeks, has not absorbed all the facts.

The water yield of the coast streams has been reported upon at intervals since the sixties. The engineers who are known to have estimated the runoff are: Mr. Herman Schussler, Prof. Geo. Davidson, Genl. B. S. Alexander, Mr. T. R. Scowden, Col. George H. Mendell, Messrs. J. P. Campbell, C. E. Grunsky, and F. C. Herrmann. Mr. Schussler, of course, preceded the others and in later reports was contemporaneous with them. He long ago made estimates of the dependable supply which are being sustained, to a remarkable degree, by later researches. Mr. Schussler was quick to perceive that the seasonal rainfall at Pilarcitos and Pescadero Creek were practically equal, and established a gaging station at Pescadero Creek to establish that fact. The rainfall records are as follows:

Season	At Pilarcitos (inches).	At Pescadero Creek (inches).
1889-90	72.09	93.67
1890-91	39.02	46.71
1891-92	52.76	40.76
1892-93	67.00	72.83
1893-94	67.87	49.94
1894-95	76.10	68.94
1895-96	56.34	54.72
1896-97	58.67	63.13
1897-98	31.16	24.35
1898-99	51.48	42.53
1899-00	52.75	47.73
1900-01	52.28	52.20
1901-02	48.54	45.50
1902-03	39.47	48.47
1903-04	56.86	55.88
Average	54.80	53.80

Mr. Schussler had an intimate knowledge of the topography of both sections as well as of the San Gregorio, and felt certain that the percentages of runoff from the three would be alike. Stream measurements at Camp Howard on Pescadero Creek were carried on for twenty years. Unfortunately the records prior to 1898 were destroyed in the San Francisco fire. The seasonal yearly quantities of the present record are shown below:

Season.	Runoff from 16 square miles of Pescadero watershed (million gals.).
1899-00	2,650
1900-01	9,180
1901-02	5,650
1902-03	4,500
1903-04	9,740
1904-05	7,390
Total	39,110
Annual average	6,518
Daily average	17.85
Daily average per sq. mile of watershed	1.115
(Say 1,000,000 gallons.)	

The mean rainfall during these years was below the average; for only two years out of the six did it slightly exceed the average, therefore it is evident that 1,000,000 gallons per square mile of catchment area is conservative. To allow for possible waste, Mr. Schussler cut this 10%, reducing the estimated runoff to 900,000 gallons per square mile of watershed.

The Pilarcitos and San Andreas waters have in the past been measured jointly. By the best process of differentiating the two, it was estimated that Pilarcitos furnished 1,000,000 gallons daily per square mile of watershed. It is now accepted that Pilarcitos and the headwaters of the coast streams have quite similar runoffs per square mile. This is an important fact, for the performance of Pilarcitos has been under strict surveillance, if not separately measured, for many years. By analogy the yield of the coast streams can be closely approximated.

Having determined the probable yield, the next step was to locate a reservoir and dam sites on the Pescadero and San Gregorio. After some search a reservoir site was found on the Pescadero, which Mr. Schussler estimates at 25,000 million gallon capacity*. Sites for diverting dams on the San Gregorio and upper branches of the Pescadero were selected. The whole catchment area was roughly assumed from the U. S. quadrangle sheets of 60 square miles, which at the assumed rate would provide 54,000,000 gallons per day. Mr. Schussler rounded this off to 50,000,000 gallons per day. In order to conserve this water (averaging 18,250 million gallons annually) a system of aqueducts and concrete lined tunnels has been devised whereby as much as 100 million gallons daily (though ordinarily only 50 million gallons) may be sent by gravity direct from the upper branches of the two creeks into Crystal Springs reservoir and without passing through the Pescadero reservoir. The balance of the Pescadero water would flow naturally into the reservoir and nearly all of the balance of the San Gregorio runoff may be diverted into the reservoir by means of a dam and concrete lined tunnel of adequate capacity. Mr. Schussler's estimate for a tunnel of 100,000,000 gallons daily is probably below the requirements. The stored water in the reservoir will have to be pumped into the gravity aqueduct leading to the Crystal Springs reservoir. So far as the writer can judge from a personal inspection and a perusal of the reports and data, he believes the scheme is capable of being carried into effect, and believes that it will form one of the chief adjuncts to the Spring Valley Water Company's system.

The reports of the first five engineers mentioned after Mr. Schussler were submitted between 1869 and 1886. These have not been available to the writer, but it is understood that their scope was limited by lack of data and in some cases to a consideration of a gravity supply only.

The next important report subsequent to Mr. Schussler's, was prepared at the request of Mr. Freeman during the past summer by Mr. Grunsky to supplement the study he made in 1908 on a gravity supply. The contents of the 1912 report have not yet been divulged to the public.†

The last report is by Mr. Herrmann, Chief Engineer of the Spring Valley Water Company. He has delved deeply into the subject and has collated a large amount of additional information. The areal rainfall has been slightly modified and a distribution made to the subcatchment areas. The report is a complete exposition of

*Flowage line to be 300 feet above creek bed. The volume in the lower 100 feet was not reckoned in the capacity of the reservoir. The capacity by a survey made in 1912 is 31,000,000,000 gallons.

†See paragraph 69 (a), page 81, Mr. Freeman's report.

the coast streams proposition. Mr. Herrmann has had a stadia survey of the Pescadero reservoir made, from which it is found that the capacity will be 31,000 million gallons or 24% larger than Mr. Schussler estimated. In the storage computations the capacity has been placed at 30,000 million gallons. Mr. Herrmann closes his admirable report with these statements:

> "The coast streams are capable of producing a gross run-off of 51.69 m. g. d. Deducting 1.5 m. g. d. for evaporation, in Pescadero reservoir, we have a net draft of 50.19 m. g. d.
>
> "Of this 50.19 m. g. d. about 16.28 m. g. d. will flow by gravity, while 33.91 m. g. d. will be pumped into Crystal Springs reservoir via the gravity conduit and tunnel."

The above quotation agrees almost identically with the former estimates of Mr. Schussler.

The same remark may be injected here as was done under the Alameda System, that the details of the development may be modified before construction work is commenced. Experience and further studies will unquestionably result in improvements.

A. O. POWELL.

Seattle, Washington, October 12, 1912.

Appendix E.

THE CYRIL WILLIAMS REPORT

By H. M. CHITTENDEN.

In paragraph 13 of my report I refer to a report on the Alameda system by Cyril Williams, Jr. The fact that Mr. Freeman appears to have made this report the basis of his drastic criticism of the Spring Valley estimate of the capacity of the Alameda system is my only excuse for giving it further attention in this place.

Superficially, the formidable extent of the report, the immense labor evidently expended upon it, its many maps and illustrative diagrams, some of them of high merit, and its exhaustive classification and indexing, inspire an expectation that the soundness of its reasoning will bear some relation to the excellence of these external features. Close acquaintance with the work fails to substantiate this expectation and compels the conclusion that it is at best a prolonged effort at *adjustment*—the adjustment of facts to a preconceived theory; and as is usually the case where one makes the mistake of embarking on an undertaking of that sort, the result has proven altogether a misfit.

The very bulk of the report makes anything like a review of it impossible here, and I shall note only a few features. They are typical, however, and furnish a keynote to the method which permeates the whole. On page 215 occurs the following paragraph:

> "Actual measurements of Alameda Creek have been taken for the last 22 years, but the S. V. W. Co.'s discharge records are considered too high on account of submerged weir conditions during high floods and infrequency of readings during such seasons. The average for 21 years according to the S. V. W. Co.'s computations gives 120 m. g. per day, or 72 m. g. per season per square mile. The average for three seasons, 1897-8, 1898-9, 1899-1900, upon which our estimates for safe yield are based, gives 48.3 m. g. per day, or 24.3 m. g. per square mile for the season."

This paragraph, which is the basis of practically all of Mr. Williams' hydrographic study, will be, I believe, repudiated by every engineer who gives it candid consideration.

His arbitrary reduction of nearly 10 per cent. in the Spring Valley unrevised estimates by cutting out the largest water-producing year in the record is indefensible, considering the large part which storage is intended to play in the operation of the developed system. If "freak" years are to be omitted, it would be more rational to omit the very dry season of 1897-8, for it plays a far less important role in the matter of supply than does the season actually rejected.

As to the effect of weir submergence, it would naturally occur to any engineer that the steep slope of that stream might give a velocity of approach at high stages which would possibly more than offset the effects of submergence in reducing the results of the formula. Recent studies have demonstrated this to be the case.

The infrequency of gauge readings at high stages, far from giving excessive results, as Mr. Williams assumes, has been shown to give slightly deficient results.

The adoption of a three-year period of excessive drought as the basis of efficiency of the Alameda system shows a failure to comprehend the fundamental principle of its proposed development in which storage is to play a pre-eminent part. Further evidence of this conclusion is the statement that "run-off estimates for safe yield must be based on a period of drought," yet Mr. Williams should know that the capacity of the storage system here proposed extends beyond the limits of any known period of drought. His refusal to recognize outside storage, though an integral part of the whole scheme, and his arbitrary limitation of the capacity of the Calaveras reservoir to only a little more than 50 per

cent. of that actually proposed, are additional proofs either of a failure to comprehend the system or a deliberate purpose to reject it in favor of one of his own.

Another fundamental error of method is the assumption, in distributing the Alameda run-off, of a flat percentage for Calaveras of 40 per cent. of the whole watershed. This might be all right in comparing long periods, but it is utterly inadmissable when it comes to taking care of water as it runs off year after year. It is wholly unrepresentative of the facts as they exist and quite destructive of any correct conclusion as to what can be done in a storage problem like that of the Alameda Creek watershed. It gives a disproportionately large flow in time of freshet when his small reservoir cannot conserve it, and a disproportionately small flow in low water when all can be conserved.

I have been twice through the report with as much care as I found it possible to bestow, but I do not pretend to have made the careful analysis given by Mr. Anderson to the whole work, and by others to certain special portions. I shall refer briefly to their opinions.

As to Mr. Anderson's review, if only one-tenth of the vagaries, contradictions and inconsistencies which he has pointed out are true (and they all bear *prima facie* evidence of correctness), it would be sufficient to deprive the conclusions of the report of all value.

Messrs. Mulholland and Lippincott, after a thorough study of the report, so far as it bore on the conclusions of their own report previously submitted to the Company, state that they "see no reason for a modification" of their previous findings.

Professor Branner closes a considerate criticism with the remark concerning Mr. Williams' theories of Livermore geology that he "has drawn conclusions which a professional geologist would not venture to draw and with which I do not agree."

It is worth while to note that this long-drawn-out study relates, after all, to a relatively very small matter, for when it comes right down to the point, the whole milk in the cocoanut of Mr. Williams' contention about the Livermore gravels amounts to less than 10 per cent of the Spring Valley system, exclusive of its artesian and San Joaquin sources. Mr. Williams seems to have appreciated the grotesqueness of this situation and on page 4 of his report attempts to justify his course on the ground that the "uncertain nature of this supply * * * * calls for a far more thorough study", etc.,—an explanation which will satisfy no one but himself. I shall not undertake to fathom the motive behind this extraordinary performance further than to observe that it certainly was not impartial investigation. Mr. Williams' reasoning and conclusions are so biased and warped in a particular direction as effectually to negative any such hypothesis, and to leave no doubt that, with an opposite bent of mind, he would have derived from the same data a totally different result. For this reason I do not consider his work entitled to confidence, and I cannot help feeling that if Mr. Freeman had probed this foundation of a large section of his own report with the same thoroughness that he would apply to a great dam or other important structure, he would not so confidently have erected thereon his imposing edifice of criticism; nor so willingly have side-tracked the experienced judgments of men like Schussler, Mulholland, Lippincott, Branner and others in favor of an authority whose report is of such questionable character.

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